Cassier's Magazine

Engineering Illustrated

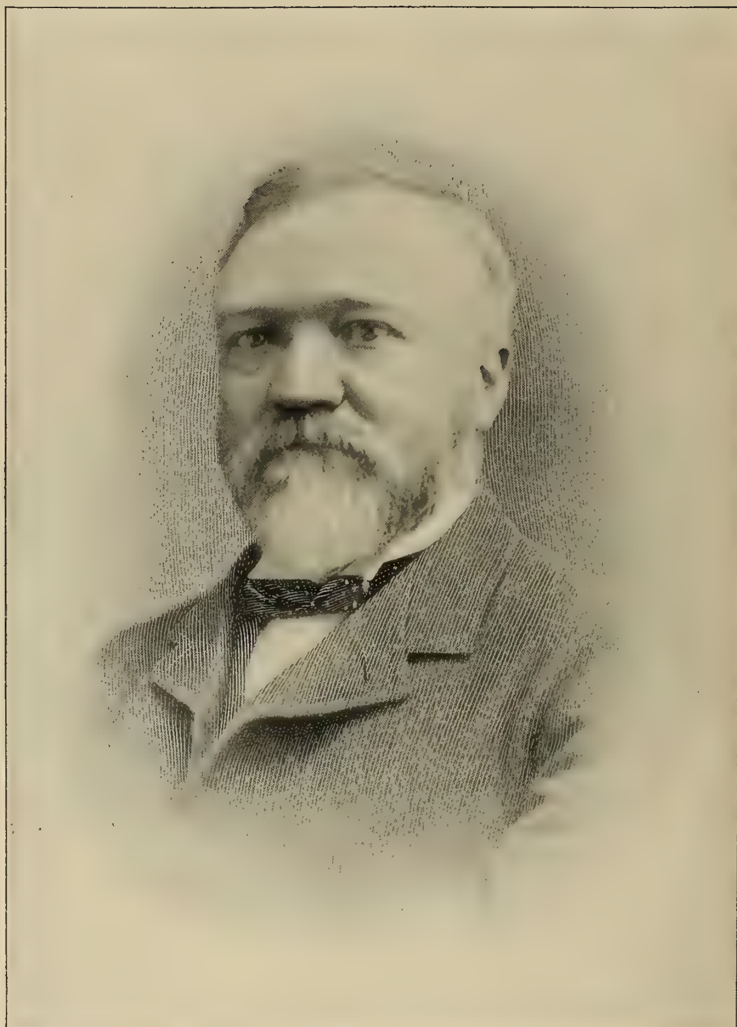
Volume XII

May—October, 1897

The Cassier Magazine Company
World Building, New York
33, Bedford Street, London

PRESS OF LOUIS CASSIER & COMPANY, NEW YORK AND LONDON.

INDEX TO VOLUME XII.



FROM A PHOTOGRAPH BY MACINTYRE, DUNFERMLINE, SCOTLAND.

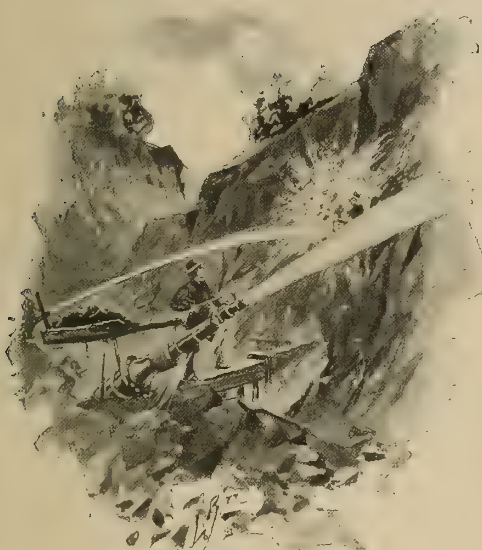
Truly Yours
Andrew Carnegie

CASSIER'S MAGAZINE.

VOL. XII. MAY, 1897. No. 1

ELECTRIC POWER FROM HIGH WATER HEADS.

By John E. Bennett.



HYDRAULIC "GIANTS."

IN the application of water power to the generation of electricity, the far western portion of the United States has probably been the scene of as interesting and extensive developments as any other part of the world. Particularly true is this of California, the gold State, where hydraulic mining may have been responsible for the more rapid development of the idea of getting water power from exceptionally high heads, rather than from great volumes.

As late as 1891, Justice Field, writing from Washington to Senator James G. Fair, of San Francisco, stated that at a dinner the evening previous he had spoken of hydraulic mining in California and " of the wonderful manner in which hills were torn down by hydraulic machinery. I stated that I understood you to say that such was the force of water thrown through a hose when it came from 100 to 200 feet in height, that bowlders, weighing half a ton could be moved by streams playing upon them, and that the force was sometimes so great that it would be impossible to cut the stream."

Justice Field continued that much surprise was manifested at this by the company, and that he thought a smile of incredulity passed over their faces. Feeling that thereby his integrity had been called into question, he wished to write a letter to each person present, stating the facts upon authority, and to this end he applied to Senator Fair for further information " as to the power exerted by a column of water thrown by such machinery and as to what size bowlders can be moved by the force of the stream, and whether it is true that the force of the stream is sometimes so great that it cannot be cut."

In the reply which Senator Fair made, it was stated that at the Spring Valley gold mine in Cherokee, Butte County,

THE SAN JOAQUIN ELECTRIC CO.'S FLUME, SHOWING ONE OF THE OVERFLOW GATES.

Cal., the largest stream was through an 8-inch nozzle under 311 feet head, delivered through about half a mile of iron pipe, 2½ feet diameter. "I have seen one of these streams at, say, twenty-three feet from the nozzle," wrote Senator Fair, "move a bowlder weighing about two tons, in a sluggish way, and throw a rock of 500 pounds as a man would a 20-pound weight. No man that ever lived could strike a bar through one of these streams within twenty feet of discharge, and a human being, struck by such a stream, would be instantly killed, pounded into a shapeless mass. At distances of from 150 to 200 feet men have been killed by very much smaller streams."

Of course, the only ends sought to be attained in the development of high velocity in the discharge of water from hydraulic mining nozzles was to cover distance and drive the water against banks to dissolve clay and remove bowlders. But the eye of the mechanical engineer saw in these expositions of power a use which was not thought of at the time when a stream from the hose of a fire engine suggested the practicability of hydraulic mining. It was to convert that power into a form that could be conveniently distributed, and the medium through which this was to be effected was electricity.

There was in California a condition peculiarly appropriate to the adaptation of power from such sources. California is a mountainous state. It is ribbed by the Sierra Nevadas, the Coast Range parallels its seaboard, and in the south the Sierra Madras, the San Jacintos and other ranges give a scenery in which, wherever you go, there are mountains always in sight.

In nearly all cases the streams are small. In few parts, indeed, does the State present conditions which might be interpreted as offering advantages of water power as the term is understood in most other places. But, running down the canyons and crevices of all mountains at all times, there are streams which, if carried in closed pipes to the base of the elevations and there liberated, would, under the pressure of water within the pipe, furnish an immense aggregate of power.

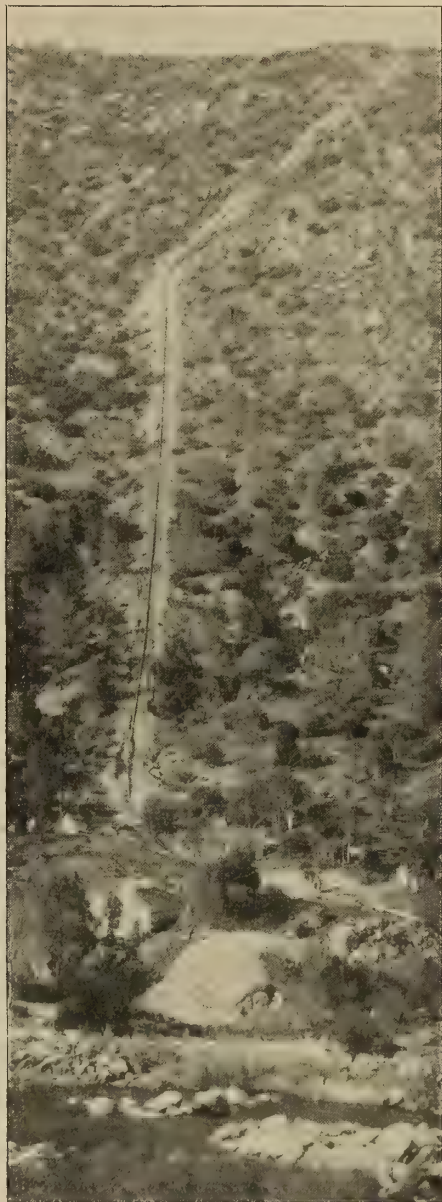
And it must be remembered that this

power can be gathered without interfering with existing applications of the streams to irrigation. No uses are made of the streams while they are running down the mountains. So far as their benefiting, by their existence, any human being, except some mountain hunter, they might as well be conducted down the mountain in a pipe as to run down a bed of rocks. When they get into the valley below, where they are needed by the agriculturist and the populous towns, they are liberated from the pipes, first having yielded their stored-up power.

After the introduction of hydraulic mining it did not take long for miners to perceive the possibility of practically utilising the power displayed at the nozzles of squirting "giants." Very soon following the success of "hydraulicking" there was introduced the pipe line, carrying the stream to the buckets of a revolving wheel which transmitted its motion to the shafting of the mine or mill. The use of power drawn from these sources and applied in this manner spread rapidly, and though it is not many years since the first installation of this character, yet it is estimated that there are now in operation on the western coast of the United States about one thousand equipments, most of them being in California. They operate mainly mining and milling machinery, the latter being principally in ore mills, grist mills and saw-mills.

But the value of high water head for power purposes was not long destined to be appreciated solely by miners and mill men. Close upon the track of these successful applications came its union with the electrical transmission plant, a character of installation then already upon the Pacific coast, but the uses of which had been confined to distributing steam power. Early in 1893 the erection of the first of this character of plant was completed and there are now in operation, or in course of construction, no less than nine of these high-head water power plants, with horse-power aggregating 30,000, and of these, seven are in California, and two in Utah.

Besides these there are two electrical transmission plants of low water heads to which the water is conveyed by penstocks of large diameter, there being about fifty-five feet of fall from the



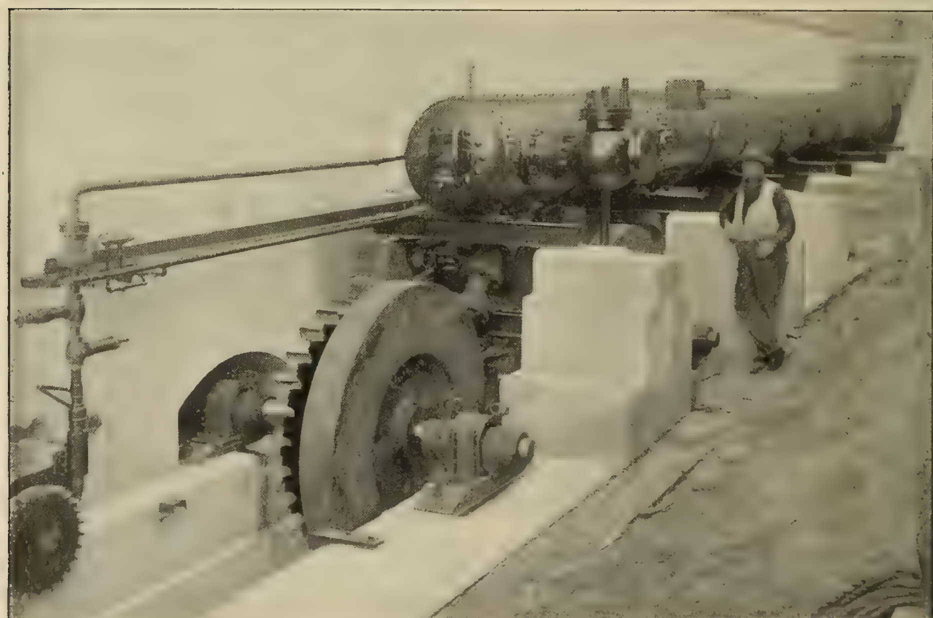
THE PIPE LINE OF THE SAN JOAQUIN COMPANY.

reservoirs to the wheels. Both of these plants are of very recent construction, the first being at Folsom, Cal., with a

HOLDING THE END THRUST OF THE SAN JOAQUIN PIPE LINE.

capacity of 10,982 horse-power, while the other is at Portland, Ore.,—the property of the Portland General Electric Co., with nearly 1900 horse-power.

The plant of the San Joaquin Electrical Company, at Fresno, Cal., one of the earliest built, is the most remarkable, both in the height of head, which is 1411 feet, and in the distance to which it transmits current, sending 1000 horse-



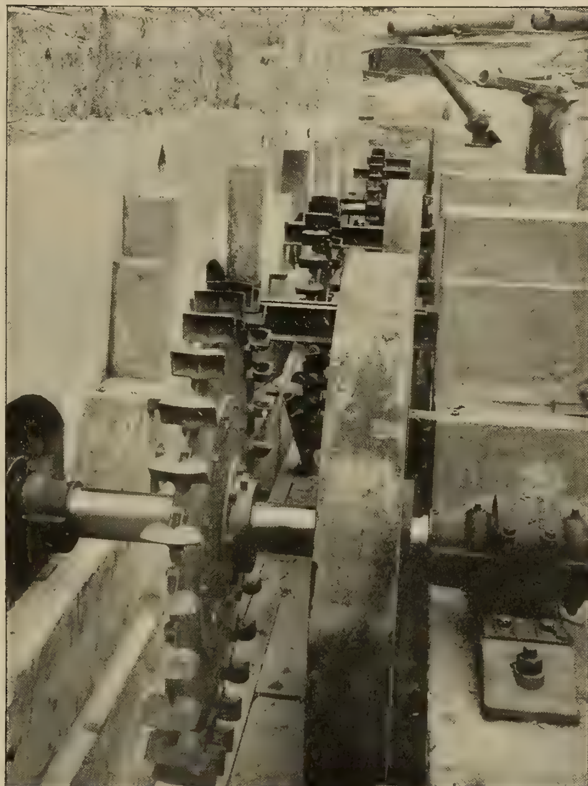
A WATER RECEIVER ABOVE A PELTON WHEEL BATTERY AT THE POWER HOUSE OF THE SAN JOAQUIN ELECTRIC CO., AT FRESNO, CAL.

power thirty-five miles away from the power house. The water is taken from two branches of the north fork of the San Joaquin river, which descends from the high Sierras. It is diverted, without the use of a dam, simply by wooden flumes. The canal—one of the engineering feats of the plant—is seven miles long, and for the first three miles has a grade of one foot per thousand, and for the next three miles a grade of seven-tenths of a foot per thousand.

The canal excavation has slopes of 1½ to 1 in earth and ½ to 1 in rock, and has a capacity of sixty cubic feet per second. It is provided with side-gates at every 4000 feet of its length. These are so arranged that any water coming into the canal from rain or any other source, in excess of that required, will spill over the top of the gates, thus making damage from flood waters impossible. The canal consists of fluming for 400 feet of the distance. The flumes are made of 1½-inch clear sugar pine, with edges bevelled, and all the joints caulked with oakum and the inner surface coated with asphaltum. Sand traps have been inserted in the canal at various points, which have given good results in keeping the canal free from sediment.

Though the stream carries a large steady supply, a storage reservoir was constructed at the upper end of the steel pipe, holding sufficient water to operate the plant for six days. This is to supply the power in the event of a washout along the flume. The pipe line is 4020 feet in length. The first 1820 feet of it are 24 inches in diameter. The next 400 feet are 20 inches in diameter; and the last 1800 feet also are 20-inch pipe.

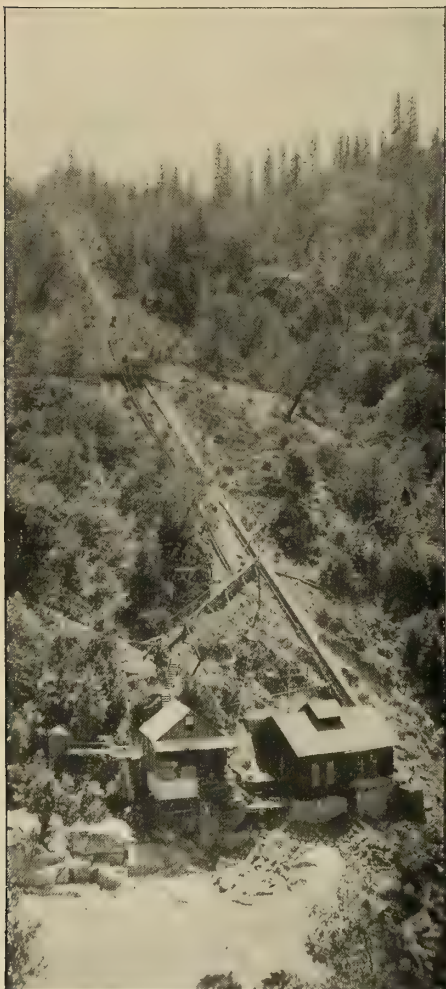
The pipe, as well as the wooden flume, is anchored to the earth in the most enduring manner. For the most part they are laid upon granite, holes being drilled in the solid rock, the bolts split for five inches from the ends and steel wedges started in the split before they were driven. Afterwards the holes were filled with melted lead. They hold the pipe by drawing on flat iron half-bands running over the top of the pipe, the bolts in this portion being sulphured in the granite to the depth of seven feet.



THE SAN JOAQUIN PELTON WHEEL BATTERY BEFORE THE HYDRAULIC RECEIVER WAS MOUNTED.

The weight of water in the pipe is about 317 tons, giving a pressure of 609 pounds per square inch at the bottom and occasioning an end thrust upon the pipe of about 93 tons, which is held at the power house by heavy masonry and solid bolting. The pipe terminates in a horizontal steel tube or cylinder, called the receiver, which is

57 feet long and 30 inches in diameter. The water wheels are mounted beneath this receiver. There are various kinds of these wheels in use in California, most of them of local invention. The Pelton, Girard and Knight wheels are among the most important. They all employ the principle of buckets bolted upon the periphery of the wheel,



THE POWER HOUSE END OF THE NEVADA COUNTY CO.'S PIPE LINE.

which is usually about 60 inches in diameter and is keyed directly upon the shafts of the generator armatures. The particular wheel used in this plant is the Pelton. The water in the pipe flows only at a rate of $1\frac{1}{2}$ feet per second, but the velocity of the jets from the nozzles, which are $1\frac{1}{8}$ inches in diameter, is nearly 1000 feet per minute. There is a jet to each wheel.

As this plant employs probably the highest head of water used anywhere, it was somewhat tentative, and the first experience in handling the water under the great pressure was interesting in many respects. The water at the nozzles acts like a solid, and the jets of the San Joaquin receiver are as hard as crowbars. The flume connects with the pipe at a wooden box enclosure, called forebay, where the pipe has two large bell-shaped openings, protected by half-inch screens. About fifty feet down on the pipe are located the gates which admit the water into the pipe below. Here there is a tall perpendicular stand-pipe, connecting with the pipe, its top being higher than the top of the reservoir. Through this the air within the pipe escapes as it is displaced by the water entering from the flume.

It was found that while admitting the water into the pipe, a tremendous water hammer occurred. The fluctuation from the normal pressure attained 170 pounds, dropping first ninety pounds below the normal, then sweeping over to eighty pounds above, falling back to seventy-five pounds below and up again for perhaps a minute until the normal was attained. The same phenomena would occur when the gates were closed. The relief valves which were employed were found to be useless, and only after substituting very slow-moving gates was the trouble overcome.

At the turning-on of the jets much difficulty also was encountered from the unmanageable nature of the waste water. The antics performed by this water after leaving the buckets of the wheel, when it should have properly gone out the tail race at the bottom of the wheel pit, were very curious. Mr. George P. Low, editor of the *Journal of Electricity*, of San Francisco, thus recounts the phenomena:—

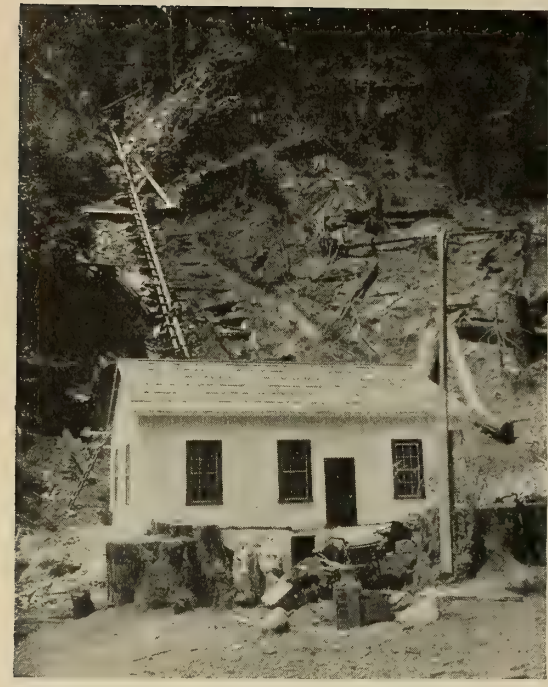
" The wheel pit, which is of solid masonry construction, was carefully closed over by heavy planking. Upon turning

THE NEVADA COUNTY POWER CO.'S DAM ON THE SOUTH YUBA RIVER, CALIFORNIA.

on the water, it refused to go out through the tail race and along the bottom of the ditch, but, instead, rolled up the sides of the pit, or followed up the water wheels to the plank covering and along the under side of the planks it rushed madly out, almost horizontally for a distance of sixty feet, where it struck a great granite bowlder and was lost in spray. The jets strike the wheels at an angle of 45 degrees from the horizontal, and the nozzles being deflecting, the impact water strikes the bottom of the wheel pit with terrific fury. After two days' operation, the water had cut under the concrete and into the seams of the bedrock, coming out in the power house and outside of it. To obviate this, a 14-inch steel pipe, 4 feet in length and having a heavy steel plate across the lower end, was let into the bottom of the wheel pit in line with the jet, the idea being that the pipe would fill with water and form a water cushion to take up the blow. Instead of doing this, however, it merely reversed the direction of the stream and the waste water landed on the top of the power house, not taking the usual course.

"Then some one recommended that the wheel pit be dammed up so as to carry two or three feet of water, which would tend to prevent the emptying of the cushion pipe, with the only difference from the preceding experiment that in addition to the waste water, the water impounded in the wheel pit was also landed on the station roof and thereabouts. Nevertheless the water cushion pipe was allowed to remain, but it was filled level with concrete and the bottom of the pit was completely floored over with 3-inch planking, which was sheathed for three feet about the nozzle with ⅜-inch steel plates. At that time the water was slightly muddy and considerable granite sand had been washed into the tail race; as a result, in less than three days, a ¼-inch jet had worn its way through the steel plate and the 3-inch planking and was at work upon the demolition of its old enemy—concrete and masonry. The heroic method of feeding a fresh cast iron plate, 1½ inches in thickness, to it as often as necessary has now been resorted to as the best solution of the problem."

The power house is equipped with



TEMPORARY POWER HOUSE OF THE BEAR CREEK POWER CO.

nozzle Pelton wheels are used for each of the three 250-kilowattt generators, delivering current at 2500 volts to the transformers, which raise it to 10,000 volts for further transmission.

Water is diverted from the South Yuba river by the Nevada County Electric Power Company, which supplies the towns of Nevada City and Grass Valley in California with light and power. The available head is 200 feet. A low ditch marks the point of stream diversion and a wooden flume 18,000 feet long, 6 feet wide and 5 feet deep delivers the water to a steel pipe of 48, 44 and 42 inches in diameter. The pipe is protected from severe water shocks by air valves, safety valves and air chambers. From the flume the pipe drops, at an angle of about 45 degrees, 320 feet to the power house, where it joins a receiver 20 feet long and 78 inches in diameter, upon which there is exerted a pressure

three 340-kilowatt multipolar there phase generators delivering current at 700 volts. Transformers raise this voltage to 11,000 for transmission. The present load of power delivered is 500 horse-power, all of which is taken in the city of Fresno. There are 5000 incandescent lamps furnished, also seventeeen 2000-candle power alternating enclosed arcs. The plant is running smoothly and gives very little trouble.

The entire electrical installation was the work of the General Electric Company, of New York.

The Redlands Electric Light and Power Company, of California, operates a plant at Redlands under a 510-foot head. The water is carried through a tunnel into a pipe line two miles long, which connects with a riveted receiver, 48 inches in diameter and 70 feet long. Double-

ALONG THE BEAR CREEK PIPE LINE.

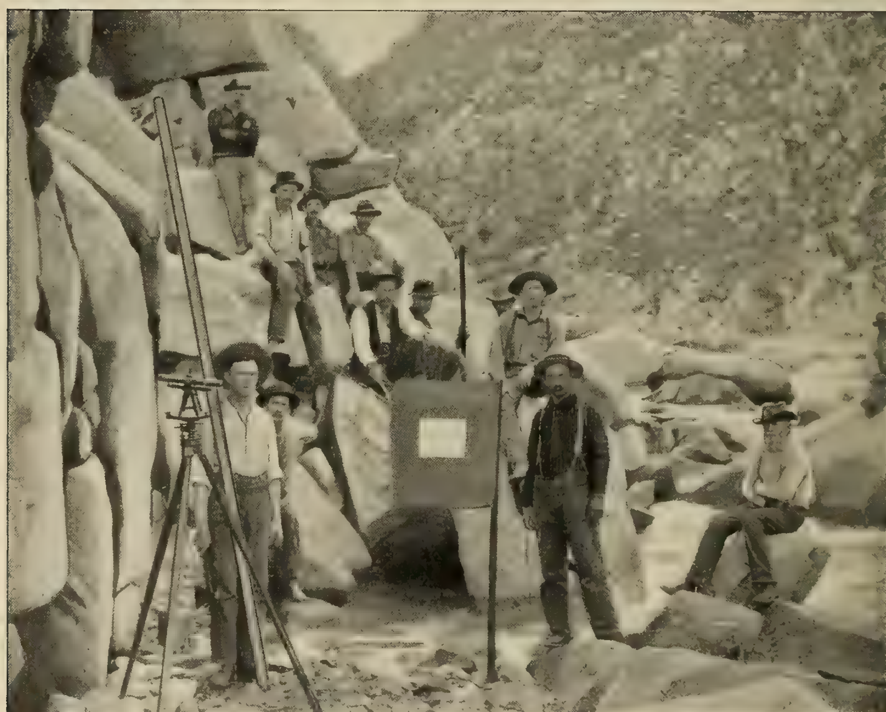
of 86½ pounds. Each of the electrical units has two 34½-inch water wheels mounted on the same shaft, directly connected, and each wheel is furnished with water through two 3¾-inch nozzles, making four jets of water applied to each unit, or eight jets in all. The wheels are controlled by means of hood valves, which uncover the nozzles as power is needed. The plant has been running and giving commercial service for about a year. At present about 233 horse-power is furnished to motors and about 4000 incandescent lights are supplied.

THE PIPE LINE OF THE POWER DEVELOPMENT CO. UNDER CONSTRUCTION NEAR KERN RIVER CANYON, CAL.

The Bear Creek Power Company takes its water from Bear Creek in the Santa Cruz mountains of California. The minimum capacity of the creek is about 500 horse-power, but there is being constructed an impounding reservoir which will increase this to 1000 horse-power. For eight months in the year, however, the capacity of the creek is 2500 horse-power. The flume is 12,125 feet long, 18 inches deep and 30 inches wide. Its construction was commenced from the bottom of the grade and extended upward, there being a stringer of 4×6-inch scantling extending on each side of the box, which constituted a railroad track over which trucks, carrying timber and supplies, were pushed during the process of construction.

The water head here is 923 feet. The flume conducts the water into 1930 feet of pipe, the first 965 feet of which are 16 inches in diameter and consist of No. 12 iron. The balance is of steel, 14 inches in diameter, graduating from No. 10 to No. 5. The pipe has banded joints throughout, all leaded. The present power house is a temporary

BEGINNING THE POWER HOUSE OF THE POWER DEVELOPMENT CO. AT THE MOUTH OF KERN RIVER CANYON.



THE FLUME GRADE REACHING WATER LEVEL.

one. The wheel is 46 inches in diameter, with a capacity of 500 horse-power at 600 revolutions per minute. It is so mounted that it may operate one 150-kilowatt generator on each side, though at present but one such generator is in place. This is a two-phase Westinghouse machine. The 1100-volt current which this develops is raised by two 75-kilowatt self-cooling transformers to 10,000 volts when it is transmitted.

The present output of this plant is carried a little over seventeen miles and is delivered to the Santa Cruz Electric Light and Power Company. The Bear Creek company has recently placed an order with the Westinghouse company for a duplication of the above plant, when it will deliver power twenty-six miles to the town of San Jose. The Westinghouse company has also put in a like plant for the Central California Electric Company, which transmits from New Castle to Sacramento, a distance of about twenty-two miles. It delivers about 800 horse-power, which is drawn from a water power of several hundred feet head.

One of the plants under construction, but nearly completed, is that of the Power Development Company, of San Francisco, which is located at the mouth of Kern river canyon, on the edge of the Sierra Nevada mountain, sixteen miles northeasterly from Bakersfield in Kern County, Cal. The power is to be conveyed by six No. 4 B & S copper wires to the distributing station in the town named, thence through a distributing system to the various points of use. The water is diverted from Kern river

A TOUGH POINT ON THE KERN RIVER FLUME GRADE.

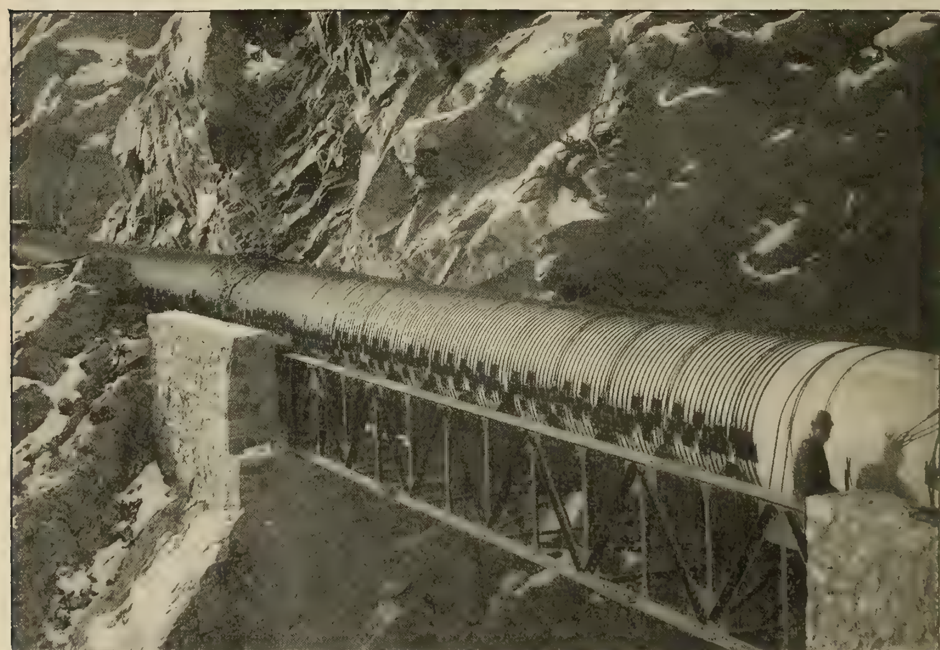
by simply tapping it in the canyon, no dam or reservoir being used or required. There is water at all times in the river sufficient to develop 7000 horse-power at the power house.

The flume which the company has constructed will carry about 18,000 cubic feet per minute; it is 9000 feet long and delivers the water into a pipe made of sheet steel, 600 feet long and 66 inches in diameter, which terminates at the power house in a steel receiver of the same diameter, 60 feet in length. In descending from the flume to the power house the pipe drops 200 feet, and the pressure of water in the receiver is about eighty pounds per square inch.

The plant now being installed consists of two 450-kilowatt twenty-eight pole General Electric alternators, which are to operate at 257 revolutions per minute, making 7200 alternations. The current is of 550 volts and is stepped up by transformers to 11,000 volts and received at the sub-stations with a 7½ per cent. line loss. The distributing system carries current at about 2000 volts. The alternators are directly connected with water wheels, two to each unit, making four wheels in all. They are of the Girard type, and are the largest of the type which have yet been built.

The plant of the Pioneer Electric Power Company, of Utah, is now nearing completion. It will transmit power primarily to Ogden, Utah, will send its surplus to Salt Lake City and run a railway between the two points, a distance of about twenty-five miles. It will develop over 10,000 horse-power. At the junction of the Ogden river and Wheeler creek a dam is being built which will be 60 feet high to the overflow gate and 75 feet high to the top of the work. The base will be 93 feet thick and the top 16 feet. The total length, from wall to wall, will be 460 feet. A wagon road will cross the river on the top of the dam, which will back up water over an area three miles long.

There are about 2000 feet of 10 x 10-foot tunnels cut through rock on the line of the trench where the wooden stave pipe is being laid. This pipe will be five miles long, made of 2 inch Oregon



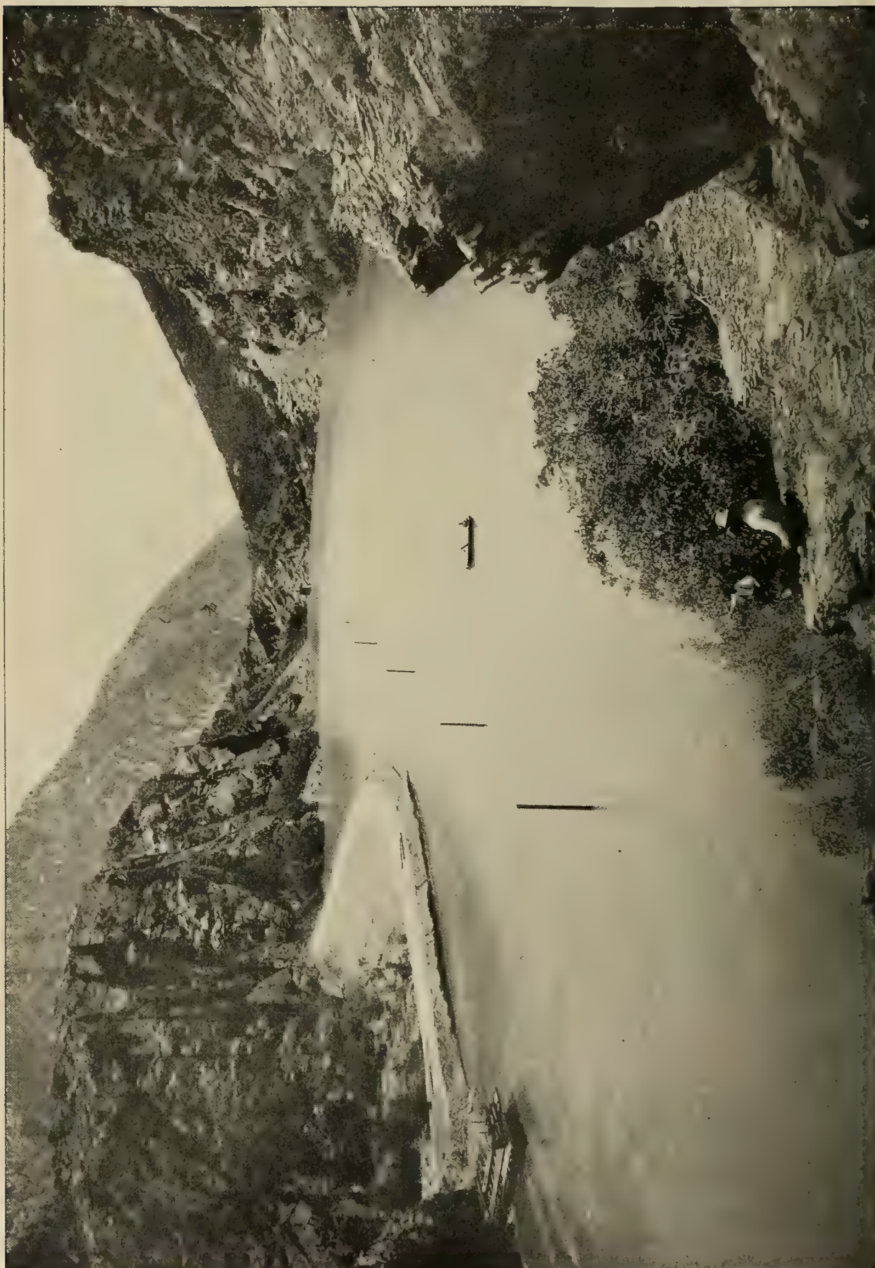
ALONG THE 6-FOOT WOODEN PIPE LINE OF THE PIONEER ELECTRIC POWER CO. IN UTAH.

PUTTING DOWN THE 6-FOOT WOODEN PIPE OF THE PIONEER COMPANY.

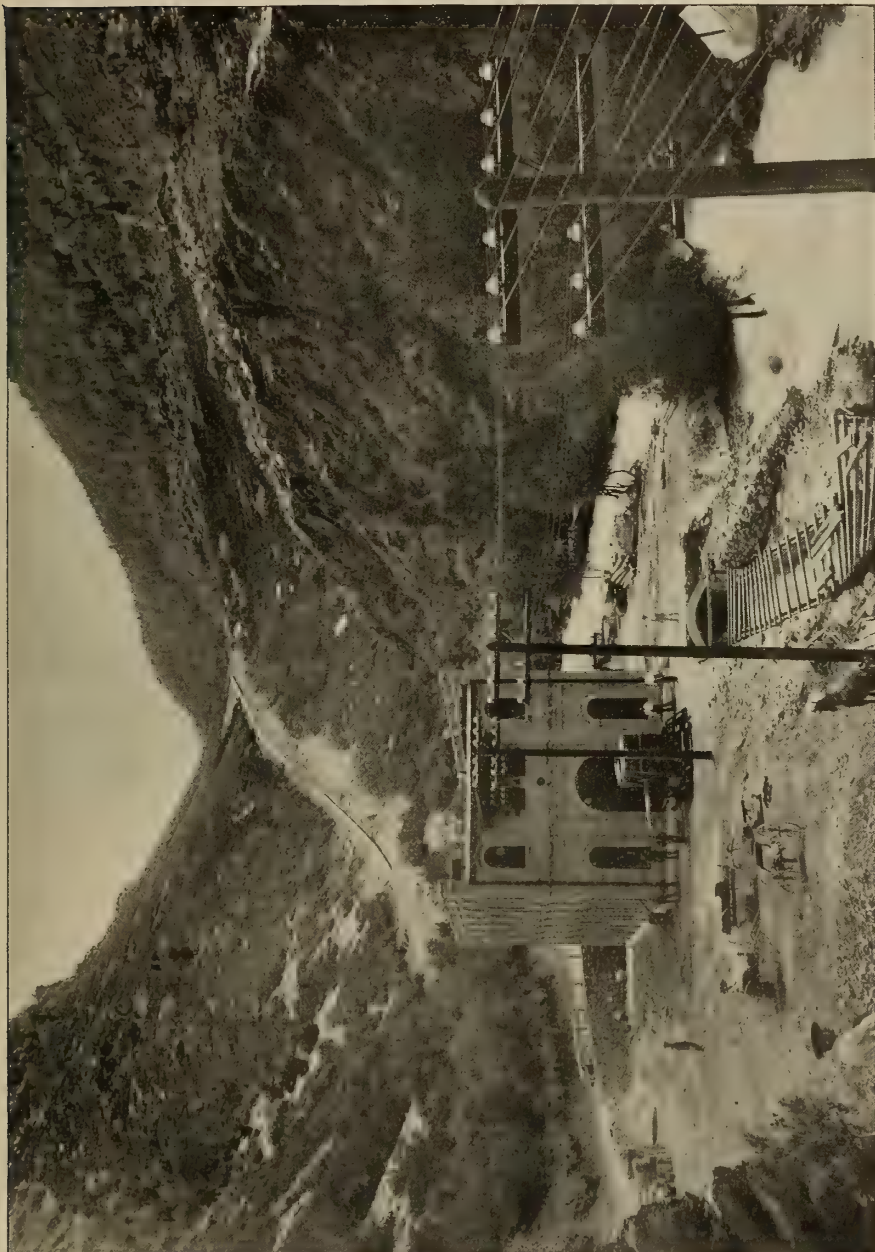
pine, the staves being so arranged as to break joints all along the pipe. The latter is held together by 87,000 steel bands three-fourths of an inch thick, drawn by screws upon steel shoes, which surround the pipe at intervals of a few inches along the entire five miles. There are man holes for washing out sand from the pipe at various places along its length; also relief valves at the top of every vertical bend for the escape of air.

Joined to this wooden pipe is a steel pipe 4517 feet long, of a thickness varying from eleven-sixteenths to three-eighths of an inch. The diameter of both wooden and steel pipe is six feet in the clear. The head at the power house is 450 feet, and there are two receivers from which the water will be delivered upon Knight wheels.

The electrical equipment consists of five 1000-horse-power twenty-four pole three-phase General Electric generators, each wound for 2300 volts. The generators are directly connected, as are also the two 100-kilowatt exciters. There are nine 250-kilowatt transformers, which will raise the generator potential



THE DAM OF THE BIG COTTONWOOD POWER COMPANY ON BIG COTTONWOOD RIVER, UTAH.



POWER HOUSE AND PIPE LINE OF THE BIG COTTONWOOD COMPANY, NEAR SALT LAKE CITY, UTAH.

THE 6-FOOT STEEL PIPE LINE OF THE PIONEER COMPANY, SHOWING CONCRETE ANCHOR BLOCKS AT ELBOWS

from 2300 to 15,000 volts, at which pressure 2000 horse-power will be transmitted to Salt Lake City; the balance will be sent to Ogden at 2300 volts.

The Salt Lake current will be transmitted over six No. 1 wires to a station in that city, where it will be again reduced by nine 250 kilowatt transformers to 2300 volts for distribution.

Another Utah enterprise is the Big Cottonwood Power Company, which works under a 380-foot head, the water being drawn from the Big Cottonwood river and conducted to a reservoir from which it is taken by a steel pipe and delivered upon a 60-inch Pelton wheel, operated by two 3¼-inch jets. The current is transmitted fourteen miles to Salt Lake City. The part of the plant thus far completed forms only a portion of the original project.

In the instance of the Tuolumne County Electric Power and Light Company's plant at Sonora, Cal., the water is taken from a spring in the mountains. It is never failing in its flow. This plant operates under a 975-foot head and has a capacity of 1466 horse-power. It has a three-phase General Electric 150-kilowatt generator, and transmits its current nine miles at 10,000 volts. It operates the motors and lights of the Rawhide mine. It was installed in 1895.

Another large mining transmission plant in California is that of W. H. Garlick, at Redding. This runs under a head of 800 feet. It has two General Electric generators. The line voltage

is 2080, and the current is sent over four miles of wire, about 400 horse-power being transmitted.

The largest water power electric plant in California is at Folsom. It is a low-head installation and does not operate with impact, but with turbine wheels, of which there are four pairs. These run at 800 revolutions per minute under a 55-foot head, fed by four inlet pipes, each 8 feet in diameter. The water is taken from the American river, which is dammed above Folsom. It is designed that on each side of this dam a canal will be run, though as yet only one has been completed. This is 9500 feet long, 53 feet wide on the top and 45 feet on the bottom. It will carry water eight feet deep with such a grade that the estimated flow is 104,000 cubic feet per minute.

About 800 horse-power of this canal is used by the electrical power plant of the Folsom State prison, under which it runs. The machinery of this is operated by Leffel turbines on vertical shafts. At the termination of the canal, in front of the Sacramento company's power house, a forebay 150 feet long and 100 feet wide, and from 12 to 15 feet deep, receives the water. The power house is equipped with machinery for over 10,000 horse-power. There are four 750-kilowatt three-phase General Electric generators keyed directly upon the shafts of the turbines. Their height is 8 feet 8½ inches, and they weigh 57,887 pounds each. The transformers step up the voltage from 800 to 11,000, at which the current is transmitted over a double pole line to Sacramento, a distance of twenty-two and one-half miles.

Thus is power from hitherto unappreciated sources being furnished to these western parts of the United States, mainly, as I have said, to California. The benefits and advantages which these high water heads offer in competition with coal and steam machinery are such as, in the case of each plant, to have stimulated the institution of the enterprise. It may be reckoned that in most instances the saving is the price of the fuel which such plant would consume, for the use of these mountain streams is free. It may be greater or less than this, however, according as the cost of the water works and wheels would compare with the cost of steam boilers and engines for equal totals of horse-power.

Of the fact that California and the American West has in its mountain streams most valuable means of securing power at relatively small cost there is no doubt. Being introduced in a region where the high price of fuel hitherto held back industrial development, these power supplies are clearly destined to work the most marvelous changes, of which the fruits will, in a few years, be manifest on every hand.

THE McKENNA PROCESS FOR RENEWING STEEL RAILS.

By Robert W. Hunt.

THE constantly decreasing tendency of prices of all kinds, during the past few years, has nowhere exerted a more powerful influence than on railroad management. The price charged for transportation of passengers and freight was long ago reduced below what had been supposed possible, but unfortunately it has not always been true that the service was performed without loss to the carriers. It is needless to discuss the influences of such factors as watered stocks, uncalled for branches, paralleled lines, and others. The stock and roads exist, and the problem is to successfully operate the properties under governing conditions. Results heretofore thought impossible have been obtained; but with success always comes the demand and desire for greater achievements; hence the development of what has become known as the McKenna process for renewing steel rails.

The inventor, Mr. E. W. McKenna, was for years identified with the active operating and maintenance of large railway systems. He became convinced that the cost of rail renewals was much too high, and his natural bent toward investigation and departure from accepted "ruts," led him toward his rail renewing invention; but he has been spurred on by the above influences.

As the speed of railway trains, and weight of rolling stock, and also the number of trains per day have been increased, so have the wear and tear of both equipment and roadbed. To meet this in the case of rails, a constant and progressive increase in their weight per yard has prevailed.

Under the light wheel tonnage and slow speed of the earlier railroad years, iron rails rendered good service. But as the demands on them increased, their wear became very unsatisfactory,—so much so, that at severe points on important lines they would last but a few months. As has so often happened in the economic history of the world, the want was met through the discovery of a new process, yielding a new metal, which made possible the railroad development of the present. Leaving cost entirely out of consideration, the interruptions of traffic by the repairing and renewal of track, if iron rails were now used, would make it absolutely impossible to transact the business of the great trunk lines.

The early steel rails were of what would now be considered too light sections,—from 50 to 56 pounds per yard. Even at that weight their superiority over iron ones was so great that railway managers rapidly increased the speed of trains, and weight of engines and cars. In all such affairs it seems impossible to maintain an equilibrium between different parts of a system. Thus increase in the weight of equipments, necessitated heavier-sectioned rails, more ties or sleepers to the mile, better ballast and greater care in maintenance; 60-pounds-per-yard rails were adopted,—then 65, 68, 70, 72, 75, 80, 85, 90, 95, and even 100 pounds per yard have followed.

In the tracks of railroads having heavy and rapid traffic, rails become unsatisfactory in condition long before they can be considered actually worn out. The heavier the equipment, and the higher the speed, the more serious becomes the effect of all inequalities in the roadbed. The wear of rails on

curves is of a different character from that on tangents, and different also on the outside and inside rails on curves. Then, up to the present time, no absolutely satisfactory joint, or system of splicing the ends of rails together, has been devised. As the contraction and expansion of so much metal under the varying effects of temperature must be provided for at the rail joints, the difficulty of obtaining a satisfactory result is thus increased.

As a rule, the rails fail at the joints much sooner than at other points. The oft-repeated blows of the passing wheels more or less gradually flatten and thus spread them, and sometimes the ends split. With such rails a long-accepted plan was to take them up, transport them to some point on the line where a cold sawing plant had been located, cut off the defective ends, re-drill them for splice-bolt-holes, and then relay them in the same track, or in other tracks on which the traffic was less. While this, for a time, did away with the most serious trouble from bad joints, it also, by making the rails of shorter lengths, increased the number of joints; and as the rails, back of the defective ends, were certain to be worn in an uneven manner, both in surface and line, the new ends of no two rails, formed by the cutting off, would match as closely as new ones, or, in fact, as they did before being cut off; but, of course, the absolutely low joints would have been removed.

Railroad managers very generally fail to realise the bad effect of want of accuracy in side fit at joints, their observation being confined to the top surfaces. As the freshly relaid track would start with unsatisfactory joints, and as all " bad things" are certain to increase, so long as they exist at all,—the second condition of defective joints and poor track would come much faster than with new rails. And as keeping up joints is the most expensive part of track work, an increase in the number of joints naturally increased the cost of maintenance. There would also be many rails defective in such manner that renewing by cutting off their ends would not save them, and so their only place was the scrap heap. Rails become defective and rough in many ways and places, and when they are too rough for first-class service, they should come out once for all. In the case of iron rails, they could be, and were, sent to rolling mills, cut up into short lengths, piled one on another in sufficient quantity, heated to the welding point, passed through proper rolls, and thus formed into new rails. As rail steel is so much more difficult to weld than iron, this cannot be done with old rails of that metal, and if it could be, the resulting rails would no longer possess the homogeneity which is of so much importance. The only market of great extent for scrap steel rails has been for use in open-hearth melting furnaces, and, so used, their value is but little above that of pig iron. All of the prevailing conditions have made scrap steel rails of less value than scrap iron ones; hence the very serious commercial question to the railroad manager as to their use or disposal.

Mr. McKenna, being both scientific and practical, and progressive, and also occupying official positions which had not only given him opportunities to observe the behaviour of rails in service, but, further, to investigate and experiment on actual methods of track maintenance, became convinced that it was practical to restore the worn rail to nearly its original section and condition. He found that many rails which had seemingly lost metal by abrasion appeared so simply because the steel had been displaced. In other words, the actual wear was much less than was supposed. Research showed that several patents had been issued for rolling down steel rails, and in actual practice steel rails of given sections had been cut into comparatively short lengths, which were heated, and then rolled down into new rails of much lighter weight per yard.

In fact, at several mills the practice was established to cut up rails, which, in course of manufacture, had developed such flaws that they had to be condemned as first-class, and roll them down to light sections of 35, 25, 20, and 16 pounds per yard. These were

used in mine tracks and other places requiring light work. The rails, so rolled down, were cut into such lengths before treatment, as would produce the new light-weight rail of standard length; *i. e.*, 30 feet. But to make such reduction and great change in section, the steel had to be heated quite as hot as it had been in the process of its original rolling from the ingot and bloom.

Mr. McKenna's idea was to heat the worn rail in its entirety, and cause as little reduction in weight of section as possible; in fact, seek to restore it to the original form, or else to one which should be considered more desirable, and also to restore it to perfect section and thus make it suitable for its original main track use. It is very desirable in track maintenance to have as little variation as possible in standards used; that is, as few different sections of rails, splice bars, etc., etc., as possible. Therefore, in restoring or renewing the rails, it was very important that the fishing or splice bar angles and distances should not be altered, thus permitting the same standard splices to be used on the renewed as on the original rails.

Mr. McKenna made some experiments in a small way, was satisfied that his ideas were practical, succeeded in obtaining United States and foreign letters patent, and then sought after the money to put his process into actual commercial operation. Here he met much opposition and, of course, many difficulties. As a rule, rail mill experts condemned his ideas. That they should do so was not strange. In the first place, all their energies had been directed toward increasing and cheapening the production of new rails.

Such a line of thought was to the direct pecuniary interest of the great steel industries with which they were connected. The re-rolling of steel rails, as it had been practised, required high heating of the steel, and consequent large loss from oxidation in the furnace and at the rolls, in which latter a number of passes or reductions (say, at least five or seven) were necessary, and the production had been quite small. Hence, it was figured that the cost of the proposed renewing would be too great, and the quality of the resulting rails unsatisfactory, on account of the high heat and small amount of work on the steel. That Mr. McKenna proposed using but two passes and employing a very moderate heat, was ignored.

Finally the matter was presented to the writer, and, after investigation, the latter was convinced that the McKenna process had excellent features. For years I have contended that the effect of heat and the degree of it at which work was applied, had comparatively more to do with the quality of the resulting rails than the chemical composition of the metal. Some years ago I wrote:—

"When general attention was first called to the somewhat unsatisfactory results which were being obtained from the wear of the rails made during the latter years, great stress was put upon their chemical composition, and chemical analysis was expected to tell the cause of the troble. This branch of investigation was followed, and several interesting and ingenious theories were built up. But unsatisfactory rails continued to be made, and the analyses of those which had yielded good service demonstrated that many of them were at variance with the theories, and also that their chemical composition was like that of many that had failed,—in fact, did not have any uniformity, but ran through almost the entire gamut. It would seem that some other than chemical causes must be sought to account for their good wear and the bad behaviour of others. Rails made by Messrs. John Brown & Co., of England, and put down on American railroads some years ago, have been generally held up as ideal rails, and the American makers for a long time supposed that when these rails did wear out, so that they could be analysed, the secret of their good service would be told."

As illustrative of how little regularity or purity of chemical composition influenced their wear, I quoted from the analyses of thirteen John Brown rails, which had been selected as having yielded exceptionally satisfactory serv-

ice. In these the carbon varied from 0.24 per cent. to 0.70 per cent.; silicon from 0.032 per cent. to 0.306 per cent.; phosphorus from 0.077 per cent. to 0.156 per cent.; sulphur from 0.050 per cent. to 0.155 per cent., and manganese from 0.312 per cent. to 1.046 per cent., thus showing that chemically the rails were a "poor lot;" but as the physical results had been so good, it seemed right to look in a physical direction for the cause.

It is not worth while to here repeat more of the argument, or to give more data. But in and by the McKenna process, I saw the means of improving,

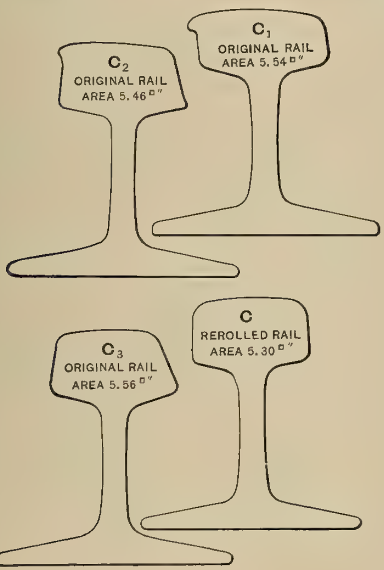


FIG. I.

rather than deteriorating, the quality of the metal. And as I knew that the rails did not require heating beyond a very moderate temperature, the loss in the furnace and at the rolls would be very small. From my rail mill experience, I felt certain that a respectable tonnage could be reached, and that thus the cost could be restricted. In short, I ventured to put myself on record as to the feasibility of the metallurgical and mechanical propositions.

In 1895 Mr. McKenna succeeded in forming a company, which leased from the Illinois Steel Company, of Chicago, their old North Chicago rail mill. It was altered to conform to the requirements of his process, and under the direct personal management of Mr. Thomas S. Blair, Jr., the works were started. Later Mr. Blair was assisted by Mr. D. H. Lentz.

It is a somewhat remarkable historical instance that in this same mill were rolled the first steel rails made in America. Later, it became one of the most prominent steel rail mills, but in the march of progress it fell out of ranks and had been abandoned as a rail mill for several years, only to be once more put in service to prove the value of this new idea.

The McKenna company expected to use the mill merely to demonstrate the practicability of the process, and also to give the railroads a chance to try the resulting rails in actual track service. No matter how firmly convinced a railroad manager may have been as to the value and safety of the rails treated by the process, it was natural that he should prudently hesitate to give them his unqualified approval and general adoption until after at least one winter's experience with them in service.

While the mill ran, there were renewed about 3350 tons of rails for the Chicago, Milwaukee & St. Paul; Atchison, Topeka & Santa Fe; Chicago, Burlington & Quincy; Michigan Central, and Baltimore & Ohio railways. These rails were at once put in service, and have given, and are to-day giving, satisfactory results. The first lot of rails,—about 400 tons,—treated at the experimental mill were from the Chicago, Milwaukee & St. Paul Railway, and comprised two patterns of 56-pound and two patterns of 60-pound rails. The fishing angles of these four lots of rails were all different, but were changed in the renewing process to conform to the established standard 60-pound rail section angle bar in use upon that road.

The data covering the 56-pound section are as follows:—

Original weight	56	lbs. per yard.
Weight when received at mill	54	" "
Weight of renewed rail	51.61	" "
Reduction from original weight	4.39	" " or 7.84 per cent

Fig. 1, given on the preceding page, shows three sections of worn rails, C_1, C_2 and C_3. These sections were represented to have been originally 60 pounds per yard, but it is fair to assume that there was some mistake about this statement, as the templets, cross sec-

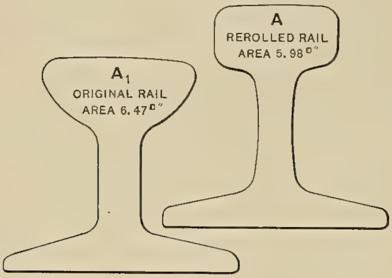


FIG. 2.

tioned, show the average weight of the worn rails to be 55.5 pounds per yard. This would indicate a loss of 4.45 pounds per yard by abrasive or attritive wear. As this is abnormal, the presumption is reasonable that the original weight did not exceed 58 pounds per yard. The sections given show the different ways in which steel rails wear, together with flowage of metal—*i. e.*, excessive curve wear, ordinary curve wear, and tread wear. The fact that these different forms of worn rails, varying in weight from 54.6 pounds to 55.6 pounds per yard, were all renewed to the standard *C* (Fig. 1), weighing 53 pounds per yard, demonstrates that the maximum reduction due to the process need not exceed 2.5 pounds per yard, and the resultant product of any lot of worn rails will be within five pounds of the original weight.

Sections *A* and A_1, in Fig. 2, represent rails from a lot of John Brown rails that had been in the track of the Baltimore & Ohio Railway for twenty-nine years. They were originally designed for some form of the Lamborn joint. The special significance in this case consists in the fact that the fishing angles were changed to admit of the use of modern joint material; or, in other words, they were altered so as to take the angle bar fitted to the American Society of Civil Engineers' 60-pound section.

The sections *B* and B_1, Fig. 3, were taken from a lot of English rails sent to the mill by the Michigan Central Railway. There were in this lot about 600 tons of original 60 and 65-pound rails that had been in service in the tracks of the New York Central Railroad for a number of years. These rails were of five different patterns, and came from nine different mills,—seven foreign and two American mills. They were all successfully renewed to a satisfactory standard. The sketch shows one of the original 60-pound rails before and after treatment.

It was not to be expected that the chemical composition of the steel should be altered by either the low heat to which the rails would be subjected or by the rolling, but as some railway officials expressed fear of such results, a number of analyses were made, the results giving the chemical composition of the rails before and after treatment. A sample of the results obtained is appended, and as, of course, the samples, while being from the same rail, were not from exactly the same place, the small variations are not greater than might

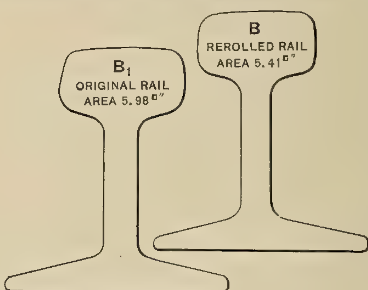


FIG. 3.

be expected. The analyses represent a "Dowlais" rail:—

	Before.	After.
Silicon	0.048	0.045
Sulphur	0.103	0.101
Phosphorus	0.080	0.081
Manganese	0.65	0.64
Carbon	0.564	0.564

The principal trouble experienced in conducting the renewing process was encountered in the heating furnace. A furnace of the Lauth type was used, and

it was found that to secure a comparatively uniform temperature throughout the entire length of the rails, the heat had to be made so great that in view of the small amount of work given to the rails in the rolling, the physical character of the steel was changed; it was rendered coarser in grain, and, hence, injured. After numerous alterations in the construction of the furnace, uniform and satisfactory results were obtained. The rails were charged in at one end of the furnace and drawn out at the other. It was feared that in pushing the rails into the furnace their ends would plough into, and thus tear up, its sand bottom. The rails were charged heads up, and it was found that, happily, the effect of the heat on the rail caused it, as soon as it began to enter the furnace, to curve slightly upward, thus providing a curved surface to meet the bottom and pass over it with little, if any, disturbance.

The loss in heating and rolling ran from 0.05 per cent. to 0.08 per cent. With one heating furnace the product was over 100 tons per turn. After being brought up to a bright red heat, the rails were drawn from the end of the furnace opposite to that used for charging, and carried by a steam-driven carriage to the back side of a three-high set of rolls, and entered between the top and middle rolls. After passing through they fell upon driven rollers, and by them entered into the final or finishing pass between the middle and bottom rolls. They were then carried to the hot saws in the usual way, and after being cut to the desired lengths, were put on the hot bed to cool, subsequently being cold-straightened and drilled for splice bolts. On some orders the rails were cut to the standard length of thirty feet. Other roads desired them cut as long as possible, with thirty-two feet as the maximum, then decreasing by six inches. In this case the sawing would take out one old bolt hole at each end. In fact, the position of such old holes, to a large extent, controlled the sawing.

After having fully demonstrated the practicability of his process, and as the Illinois Steel Company desired the use of their mill, Mr. McKenna ceased experimental operations, and sought to organise a company to build a mill specially designed for the process. The peculiar financial stringency which prevailed so generally in the United States prevented success until a short time ago. The company is known as the McKenna Steel Rail Renewing Company, and has contracted with the Lewis Foundry and Machine Company, of Pittsburg, to build a complete mill, to be located at Joliet, Ill. The contract requires the mill to be completed by June 1, 1897.

The rail train is a tandem one, with two sets of two-high rolls, each set driven by its own engine. In the first set, or what may be called the forming rolls, there will be at least three grooves, each designed to receive a definite form of a worn rail. After passing through it, the rail will be carried on driven rollers to the second, or finishing, set of rolls, where it will receive one pass, and then be taken to the hot saws and so on in the regular way to the straightening and drilling machines. With the two heating furnaces, the mill will have a daily capacity of at least 400 tons of finished rails.

The company will begin operations with quite large orders on their books, all of them being from the railroad companies for which they made rollings in the experimental mill.

THE MEASUREMENT OF FLOWING WATER.

By Samuel Webber.

IN response to a request from the editor of CASSIER'S MAGAZINE for a short article on "How to measure the discharge of a stream," the writer would offer the following suggestions, with notes from his own experience, promising first, however, that he does not expect to furnish any information to experienced engineers, or to go into questions or subjects, which require knowledge of the higher mathematics, or elaborate and expensive preparations and apparatus, such as Venturi tubes or piezometers. He will simply define such modes of measurement as will give closely approximate results, and may be carried out by young engineers, or skillful mechanics, by the aid of such appliances as may be conveniently at hand, or can be simply and easily constructed.

He may also say that his attention was first called to this subject very many years ago, and that he watched, with great interest, the first attempts to measure the volume of water consumed by the great American cotton mills at Lowell, Mass., made by the late James B. Francis and his corps of assistants, and beginning, according to the best of his recollection, about 1844.

The most striking feature of these early experiments, to an outside observer, was the great current wheel which was placed across the canal leading to the Merrimac mills, which completely filled the canal from side to side, and revolved with the current, its revolutions being counted, and, as it fitted closely to the planked sides at each end, and to a curved timber bed plate at the bottom, it needed only accurate notes of the depth of the water on the vanes of the wheel to calculate the area of each segment of a cylinder, and the number of these passing in a minute gave the quantity of water.

This, according to the writer's recollection, was merely a preliminary experiment, for at the same time an area of the canal just above this current wheel was converted into a square flume, about 100 feet long, with planked sides and bottom. The current velocity in this flume was measured by floats, and the results of the float measurement were corrected by those obtained from the wheel. This was before the days of the turbine, which was then just being introduced at Lowell, and before Mr. Francis' elaborate weir measurements, which served to determine exactly the amount of water passing through the wheel, and also to further check and verify the float measurements in the flume. The float measurement system was finally established, and is now universally used in determining the quantity of water consumed by the mills on the Merrimac river, although since the perfection of the modern turbine, the water is measured at Holyoke, on the Connecticut river, by the gate openings of the wheels themselves, such discharge, at different heights of gate opening, having been very accurately ascertained by thousands of experiments.

The system of measurement adopted at Lowell, and in daily use at present, is clearly shown in Fig. 1 of the accompanying diagrams. A section of the canal is encloseed in a square flume of plank, with level bottom and perpen-

dicular sides. Across this, near either end, is laid a timber, having bold, clear divisions marked on it at every foot, and numbered. These timbers may be 50 feet apart or 100 feet, or any other equal number, as is most convenient. About 6 or 8 feet above the upper timber, and below the lower one, is a timber bridge for the assistants who drop and collect the floats.

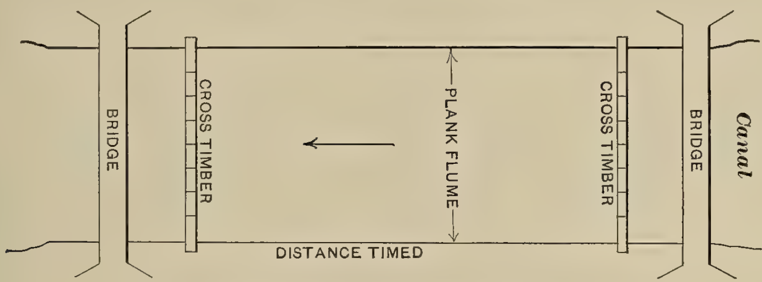


FIG. I. THE LOWELL METHOD OF MEASURING WATER.

These are tin tubes, about 2 inches in diameter, and rather longer than the depth of water to be measured. They are loaded with lead so as to sink nearly to the bottom, and float perpendicularly. The upper end should be closed with a cork to prevent the entrance of water. The assistant drops one of these tubes from the upper bridge, pointing it up stream, as he does so, so that the current brings it to a perpendicular as it passes under the timber, when the observer starts the second hand of his stop watch, at the instant of passage, and walks down to the lower timber, stopping his watch as the float disappears under that. The assistant notes the number of the division on the upper timber, where the float passes under, and also the one on the lower timber, where it is recovered, and from these the velocity lines are drawn, which show the area of the body of water passing through the flume in a given time,—a second or a minute, as it may be.

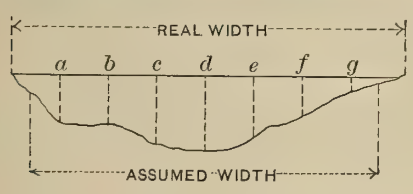


FIG. 2. MEASURING WATER IN AN IRREGULAR CHANNEL.

A gauge board should be placed on the inside of the flumes, at either end, properly graduated into feet and decimals, and the average of the observed height of water, from the bottom, multiplied by the average velocity, will give the total quantity passing the flume in the noted time.

Full and careful experiments made at Lowell by Mr. Francis, and recorded by him in his "Lowell Hydraulic Experiments," where the water, after having passed the flume, was again measured over a weir, and where the volume of the water was 294.5 cubic feet per second, showed an excess of about 2¾ per cent. in the float measurement over that given by the weir, and this is due, without question, to the retardation of the water by the sides and bottom of the flume, as there were a few inches at the bottom and on each side, not touched by the float, where the motion must have been slower, although the whole area was calculated. It is sufficient to say that an accuracy of within 2 or 3 per cent. can be obtained by this mode of measurement.

Where the sides of the canal are perpendicular stone walls, and the bottom is level, the same result, or nearly so, can be attained without the timber lining; but it is a safe plan to allow such measurement to be 5 per cent. in excess of the real flow. There are, however, many cases where the regular rectangu-

MEASURING THE DISCHARGE OF A STREAM.

lar section of an artificial canal cannot be obtained, and where the mode of float measurement, which is the most available, must be modified by the circumstances. The first thing to do is to select a site where the channel is nearly of uniform width, and the flow as direct as possible, free from obstructions and eddies, and ascertain its periphery by a line of cross soundings. Stretch a couple of white ropes across, two or three feet above the water, having the points *a*, *b*, *c*, etc. (Fig. 2), where the soundings are taken, marked on them by black knots. These ropes may be from 40 to 100 feet apart, the longer distance the better.

Prepare a set of floats, a foot longer than the depth sounded, but loaded and corked, so as to float six inches above the bottom. If tin tubes are inaccessible, use pine sticks 1 inch or 1½ inch square, and tie on weight at the bottom to the necessary amount; but have them painted white if possible. The assistant will either wade out above the upper rope, if it is a shallow stream, or drop the float from a boat, and it is an ex-

cellent plan, and saves men and time, to have a strong fish line attached to the float near the top, by which the assistant can draw it back to him after the time at the lower ropes has been noted. It is a good plan to repeat such timings two or three times, though the writer has seldom found much variation.

In calculating the area, if the stream be very shallow at the edges, omit half the distance from either shore to the first knot near it; that is, if the distance at the water's edge be 100 feet and the knots 10 feet apart, base the calculated area on a width of 90 feet, and you will more nearly approximate the flow and probably not exceed it by more than 5 or 6 per cent.

The velocity diagram obtained in such a case will be much more irregular than in the case of the square flume. When such appliances are not available, and accuracy is not necessary, an approximate result may be attained by surface floats only, but here, according to Trautwine, the excess, calculated from a surface float in mid-current, will be about 20 per cent. of the real flow. He gives the distance to be measured as 50 feet in a slow stream, and 150 in a rapid one. While these observations will apply with a considerable degree of accuracy to small or shallow streams of moderate dimensions, they will be found to be unreliable in the case of larger and deep rivers. This was found by the attempts of the United States Government engineers to gauge the flow of the Missis-

USING A CURRENT METER.

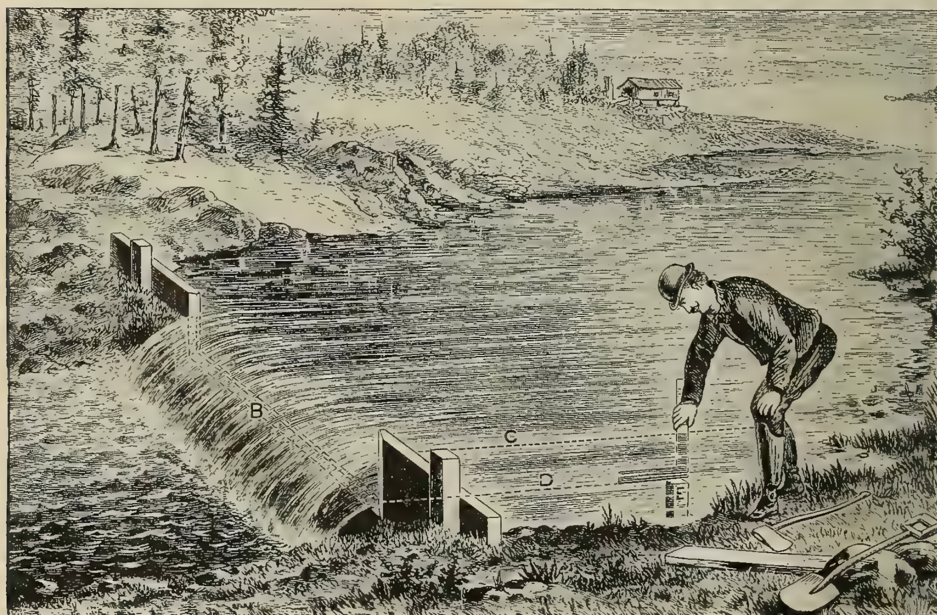
sippi river. The velocity of a float, with a loaded line attached, from 25 to 75 feet long, was found, according to the depth of the river, to be about 2 per cent. greater than that of the simple surface float.

As the gauging of such large bodies of water, however, is likely to be confined to experienced Government engineers, to whom I do not presume to offer advice, and as there are yet many points to be accurately determined, I will not occupy further space with this mode of measurement.

We will now turn to the system of weir measurement, which is the accepted standard by which all other methods are verified. This has been the subject of constant examination and experiment for many years by the most eminent engineers, and their experiments, made on a small scale, were finally repeated and verified by Mr. Francis, in 1852, on a large one, and the results published in the "Lowell Hydraulic Experiments" already referred to.

It was found that the volume of water, falling over a straight, thin-edged weir, was as the length of the weir, multiplied by the square root of the cube of the depth of water, multiplied again by a co-efficient, to be determined by experiment. Eytelwein made this co-efficient 3.40; others, slightly less; but it is now established by Mr. Francis' experiments at 3.33, the exact average of all his experiments having been 3.3318.

These experiments, as stated, were made on a very large scale. The weir was 10 feet long, and the depth of water passing over it as high, at times, as 18 inches, while the receiving basin in which the water was caught and measured, was an old canal lock, 100 feet long, by 11 feet wide and 8 feet deep, tightly lined with close planking. The quantity of water, at times, was as great as 62 cubic feet per second, and these tests were carried on for many consecutive weeks, until a satisfactory formula was conclusively established and reads $Q = 3.33\,L\,H^{\frac{3}{2}}$ in feet and decimals. In this formula L represents the length of the weir opening, and H the depth of the water flowing through it.



MEASURING WATER DEPTH ABOVE A WEIR.

This, however, supposes the water to approach the weir in a uniform channel of the same width, which is seldom the case. It is usually contracted at one or both ends, and one-tenth the height of the water, or two-tenths its height, accordingly, must be subtracted from the length of the weir to get the true length for computation, and then the formula reads, $Q = 3.33 (L - 0.2\ H)\ H^{\frac{3}{2}}$

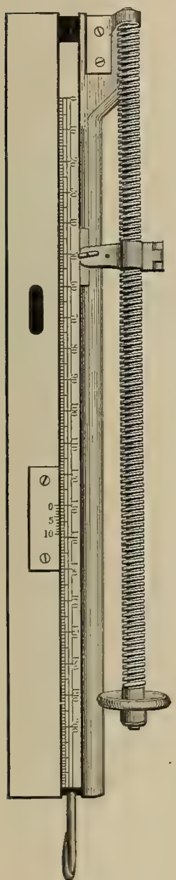


FIG. 3. A HOOK GAUGE.

This form of a flat weir, over which the water falls clearly without obstruction, and which may be of any width to accommodate the stream, has been found, by engineers, to be the most simple and generally practicable, although Professor Thomson, of Dublin, suggested a triangular notch. This is, however, a very inconvenient form, and suited only for small quantities of water.

Professor Thomson's formula for this is the square root of the fifth power of the height (in inches) multiplied by the co-efficient, 0.0051, or $Q = .0051\ H^{\frac{5}{2}}$ (in inches). Although the fifth power can be easily obtained by logarithms, which are also useful in the other formula, the triangular notch is not applicable to a large stream.

I have perhaps consumed too much time and space, in describing the history and theory of the weir, and will now proceed to its practical application. The weir may be of any convenient length, but, for convenience, should be of an exact number of feet. It should be bevelled off down stream, at an angle of 45 degrees, from a thin crest, not over ¼-inch wide, on both bottom and ends, or the edges may be made of a thin metal plate.

The height of the weir above the bed of the stream should be not less than twice, and better, three times the depth of the water flowing over it, and the fall below it, or over it, should be such as to leave a clear air chamber under the water. It will be well to make the weir wide enough so that the depth of water passing over it will not exceed 18 inches, and, if possible, not over one foot. As the surface of the water begins to fall before reaching the weir, the measure for its depth must not be taken at that point, but may be taken by a hook gauge, set in a box below the weir, which is supplied with water by a pipe running through the dam into the pond above, in which case the water in the box will stand at the same level as that in the pond.

The hook gauge, as explained in an earlier issue of this magazine, consists of a bronze or copper rod, from 2 to 3 feet long, having a needle-pointed steel hook at its lower end. It is graded in feet and hundredths, from zero at the upper end down to the point where the hook is attached. A vernier, fastened to the board to which the gauge is attached, enables the reading to be taken to thousandths of a foot. This board should be supported in a proper position, at such a height that, with the point of the hook just level with the top of the weir, the zero of the rod should agree with that on the vernier.

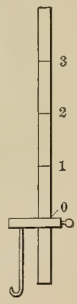


FIG. 4.

Then, when it is raised, so that the point of the hook just dimples the surface of the water, the depth of the water is read at the vernier. The level of the water in the box will agree with that above; or, the box, having a perforated bottom, may be inserted in the channel above, at least 6 feet above the weir.

Where a hook gauge is not acceptable, the usual plan is to drive down a post in the pond about 5 or 6 feet above the weir, and measure the depth of the water to the top of that, which must be just level with the top of the weir. As

this measure is liable to some uncertainty, owing to capillary attraction drawing the water up on the scale, if it is wet, the writer has devised a simple portable hook, which may be used instead, and is shown in Fig. 4.

Taking the slide clamp of a common carpenters " scribing tool," he screwed a strong wire, with a pointed hook at the end, into it, and made a scale rod, 4 feet long to fit the slide. Setting the point of the hook so that it is just level with the bottom of the scale rod, a zero line is marked on the rod, at the upper edge of the slide, and the rod is then graduated up from that in feet and hundredths, which are plainly visible, as each one-hundredth is about one-eighth inch. One's eyesight may be trusted to determine the intermediate thousandths, although if there be time and patience the graduations may be made finer.

This rod should be well oiled, so that the slide will work freely. It is very convenient and portable, and can be used on a post set in the pond with perfect ease and much greater accuracy than a yard stick or two foot rule. The depth of water thus ascertained, complete tables for the amount of water delivered may be found, either in Mr. Francis' book or in Emerson's " Hydrodynamics," in which they are given for all depths of water usually necessary, and various lengths of weir with end contractions. These tables are based on moderately still water in the pond above the weir. Mr. Francis says that a current of 6 inches per second approaching the weir, increased the flow about 1 per cent., and one of 1 foot per second, about 2 per cent.

It will be seldom that any closer accuracy will be desired than can be obtained by such observations as here noted; but if it be desirable, reference may be made to Mr. Francis' second formula for that purpose, which, with all the necessary tables, can be found in either of the books referred to. It remains to be said that in using the hook gauge, care should be taken not to raise the point above the surface of the water, but just to " dimple " it, so the point can be noted.

In locating a weir, a convenient dam may sometimes be found on a stream, on top of which it can be placed, care being taken to place it at the upstream edge of the dam, with sufficient height to give a clear air space under the fall. Otherwise, a temporary dam can be thrown across the stream, of stout plank, well braced from below against the pressure of the water, with heavy stones and timber, and made water-tight above with gravel, and sods, or clay. A low dam of this sort, with a wide weir, can be easily constructed, but a high one, is very liable to annoying accident unless very strong.

There is one other form of stream measurement which I have not noted,—the current meter method,—shown in the illustration on page 29. It is a somewhat delicate and uncertain instrument, and like the piezometer, and the Venturi tube, had better be left to the management of experienced operators. It consists of a rotary set of vanes, like a ship's propeller, and by its revolutions gives the velocity of the current. In the illustration on page 28 may be seen two observers noting a current meter in the background, while one is taking a weir measure in front.

The illustration on page 30 shows the measure taken at a proper distance above the weir, which will generally prove the most convenient and satisfactory way, and by means of the light hook and rod which I have suggested may be made very accurate.

BRITISH EXPRESS LOCOMOTIVES WITH SINGLE DRIVING WHEELS.

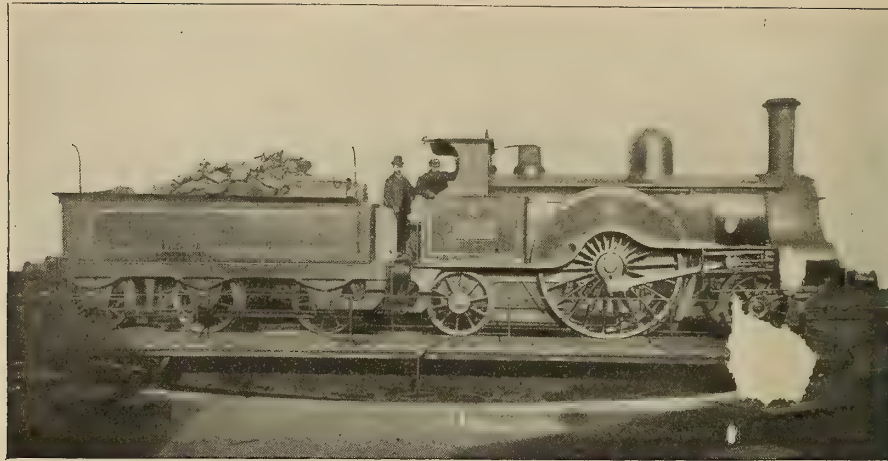
By Geo. Fredk. Bird.

MUCH uncertainty at times manifests itself, even in the technical press of both England and the United States, in discussing the locomotive engineering practice prevailing on, relatively, the other side of the water, and, as a consequence of this misconception, arguments arise, founded on erroneous premises, which convey such regrettably erroneous final impressions that it may possibly not be without interest to give, in the limits of a short article, a brief account of one almost exclusively British feature of locomotive design,—that of single driving wheels.

In selecting locomotives with a single pair of driving wheels for especial notice, there is no intention on the writer's part to give the idea that this is in any sense the "national" type. When the services of different railway companies make a demand for engines capable of performing widely varying duties in the most efficient and most economical manner possible, it would be impossible to quote one type as being preeminently "national." As a matter of fact, indeed, British express locomotives may, for general purposes of illustration, be roughly divided into two classes, having respectively one pair and two pairs—"four coupled"—of driving wheels. These may further be subdivided into six-wheel—either with a rigid wheel base or with a radial leading axle—and eight-wheel bogie engines, and still further into inside and outside cylinder engines, thus presenting in ordinary practice a variation of eight possible combinations. Of these, however, the only two combinations that are of pre-eminent importance are the first mentioned, four coupled wheels being practically a necessity for dealing with very heavy traffic and hilly roads. For the rest, they are rather a matter of the locomotive designer's personal predilection than vitally necessary to any particular service.

At the present time, if there really be any British "national" type, it would appear to be a combination of inside cylinders, four coupled wheels and a leading bogie, and so far as two of these details are concerned, it is sometimes said that the British have, in course of time, followed in the track of the American designers. For the purposes of this article, however, that much-argued point may be left undiscussed, beyond the fact of mentioning that the first coupled-wheel bogie engine, known to the writer, was Hedley's "Puffing Billy" as rebuilt in 1815, and that both coupled engines and bogie engines were built in England before a single wheel turned on an American railroad.

But while it may be granted that at present the British "national" type, if it exist, is as above stated, we must not forget that in early locomotive history the single-driving express engine played a conspicuous part, that some of the most noteworthy examples of British practice have at all times belonged to that class, and that, despite all temptations to change, more than one locomotive engineer has adhered steadily to that type for express passenger traffic. And, furthermore, the object of this article is to show to American readers that, at the moment of writing, there is



FROM A PHOTOGRAPH BY F. MOORE, LONDON.

THE "LADY OF THE LAKE" ON THE LONDON AND NORTH WESTERN RAILWAY

in existence a collection of engines of the single-driving type running at the heads of some of the fastest express trains in the world, whose performances, in view of the special services demanded of them, could probably be scarcely equalled by any other type.

First on the list of these single drivers is the well known "Lady of the Lake" class on the London and North Western Railway, the details of which were worked out by the present locomotive superintendent of that line, Mr. F. W. Webb, when in the drawing office under the late chief, Mr. John Ramsbottom. The first engine of the class, "Problem," was put on the metals in 1859, and so successful did it prove that between that year and 1865 no less than sixty engines of the class were built, all of which are, the writer understands, still running. One of these, the "Lady of the Lake," which is shown in the illustration on this page, was awarded a bronze medal at the International Exhibition of 1862, which it still proudly carries just above the number plate on the cab.

These engines are, judged from a modern standpoint, remarkably light, weighing only 27 tons, of which 11½ rest on the driving wheels. The latter are 7 feet 7½ inches in diameter, and the cylinders, 16 inches in diameter with a 24-inch stroke. The tenders are fitted with Ramsbottom's water-scoop feed for picking up water while running, and this capacity has allowed them to take part in some memorable achievements. Thus, on January 5, 1862, a special train, bearing the famous Slidell-Mason dispatches from Washington, was conveyed by engines of this class from Holyhead to Stafford, 130½ miles in 145 minutes, and thence to Euston, the whole distance of 264 miles being run, with the one intermediate stop at Stafford, in five hours.

More recently two engines of this type, "Waverley" and "Marmion," were selected during the historic race to Edinburgh in 1888, to take alternate duty in drawing the West Coast train each day from Euston to Crewe, without a stop, the distance of 158¼ miles being scheduled, during the last half of August in that year, to be covered in exactly three hours, while it occupied but 166 minutes on at least one occasion and was frequently done well under time. It should be remarked that the train was comparatively light, four eight wheeled coaches, weighing about 22 tons each, being the daily load; but none the less the feat was remarkable in view of the ages of the locomotives. Indeed, so capable are these little engines still judged to be of dealing with moderate loads at high speeds that Mr. Webb is even now engaged in rebuilding them as a class for further service.

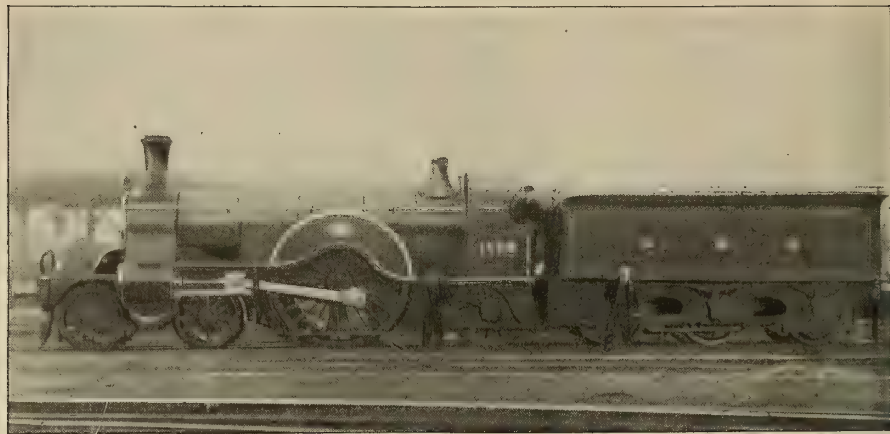
In their rebuilt form they will be heavier, 31 tons, 7 hundredweight, of which 14 tons, 5 hundredweight will be on the driving wheels, these latter being increased in size to 7 feet 9 inches by the employment of thicker tires. In this form they will probably enter on a new career of usefulness.

A noteworthy type of very similar design, but larger, was introduced at about the same time on the Caledonian Railway, by Mr. Benjamin Connor. These were also six-wheeled, outside cylinder engines, with 8 feet 2-inch drivers, and 17¼-inch by 24-inch cylinders, and an engine of this class shared with the "Lady of the Lake" in the honours of the 1862 exhibition. These, however, unlike the North Western engines, have now closed their railway career after having, during some thirty years, earned the reputation of being genuine "flyers."

At the present time the Caledonian Railway possesses but one single driver equal to modern requirements, the historic No. 123 shown on this page, a bogie engine which accomplished heroic feats with the West Coast racing train during 1888. This engine, designed by the late superintendent of the line, Mr. Dugald Drummond, who has now charge of the locomotive department of the London and South Western railway, weighs 41 tons 18 hundredweight, of which 17 tons are on the drivers, which are 7 feet in diameter, driven by 18-inch by 26-inch cylinders. No. 123 won its spurs, so to speak, during the railway race, on one occasion taking the four coaches over the road from Carlisle to Edinburgh, 100¾ miles, with a rise to be surmounted of 1015 feet above sea level, in 102½ minutes. But though this fine engine thus performed wonders with a light train, the general character of the road and the ever-increasing average weight to be drawn has rendered necessary the service of powerful four coupled engines for the best express work, and No. 123's successors have all been of that class, the latest type, the "Dunalastairs," designed by the present locomotive superintendent, Mr. John F. M'Intosh, being amongst the most powerful in the world and performing duties commensurate with their huge bulk and power. No. 123 has been relegated to a fast service between Aberdeen and Perth, running daily with a train averaging ten coaches and weighing 210 tons, the longest run without a stop being 32½ miles, and the fastest booked speed, 22½ miles in 40 min-

FROM A PHOTOGRAPH BY FORBES.

CALEDONIAN LOCOMOTIVE "NO. 123."

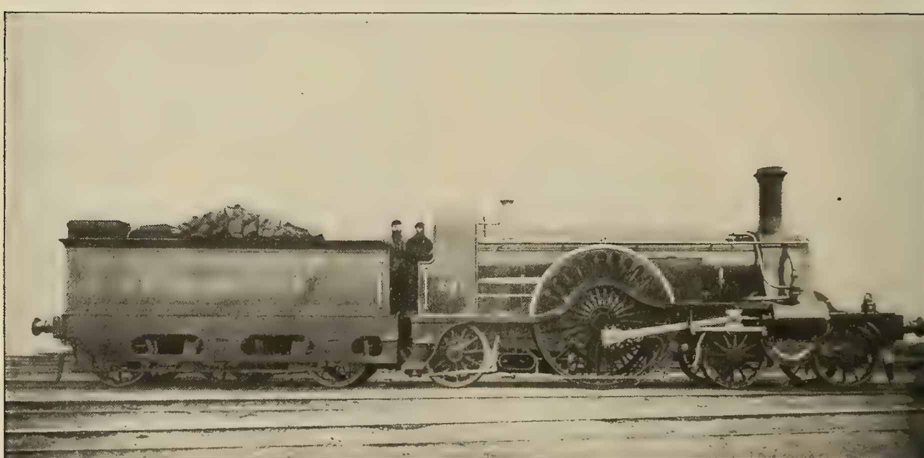


FROM A PHOTOGRAPH BY A. J. BREWER.

THE GREAT NORTHERN LOCOMOTIVE "NO. 1008."

utes. On this service the engine burns about 45 pounds of Scotch coal per train mile, a consumption that is not so heavy as it appears, in view of the load and the far from easy road covered.

Unquestionably, the most famous among modern single-driving engines are the 8-foot wheel bogie locomotives on the Great Northern Railway. These, the original design of the late Mr. Patrick Stirling, have probably an unequalled record among express locomotives by reason of the fact that, though the first of the class was brought out quite twenty-eight years ago, the type has been perpetuated and repeated with extraordinary success ever since, with scarcely any change even of details. The illustration of No. 53 on this page, is sufficiently close a likeness to the first one put on the metals to be typical of the actual No. 8 which was the pioneer, and it is only necessary to carry one's mind back some thirty years in order to realise how marked an advance these engines were upon the practice of the day. Mr. Stirling was one of the sturdiest adherents of the single-driving engine from the start of his career, and there can be no doubt that to his successful carrying of theory into practice in the case of these bogie engines is due



"NO. 53" OF THE GREAT NORTHERN RAILWAY.

the present existence of single-driving bogie engines on other lines.

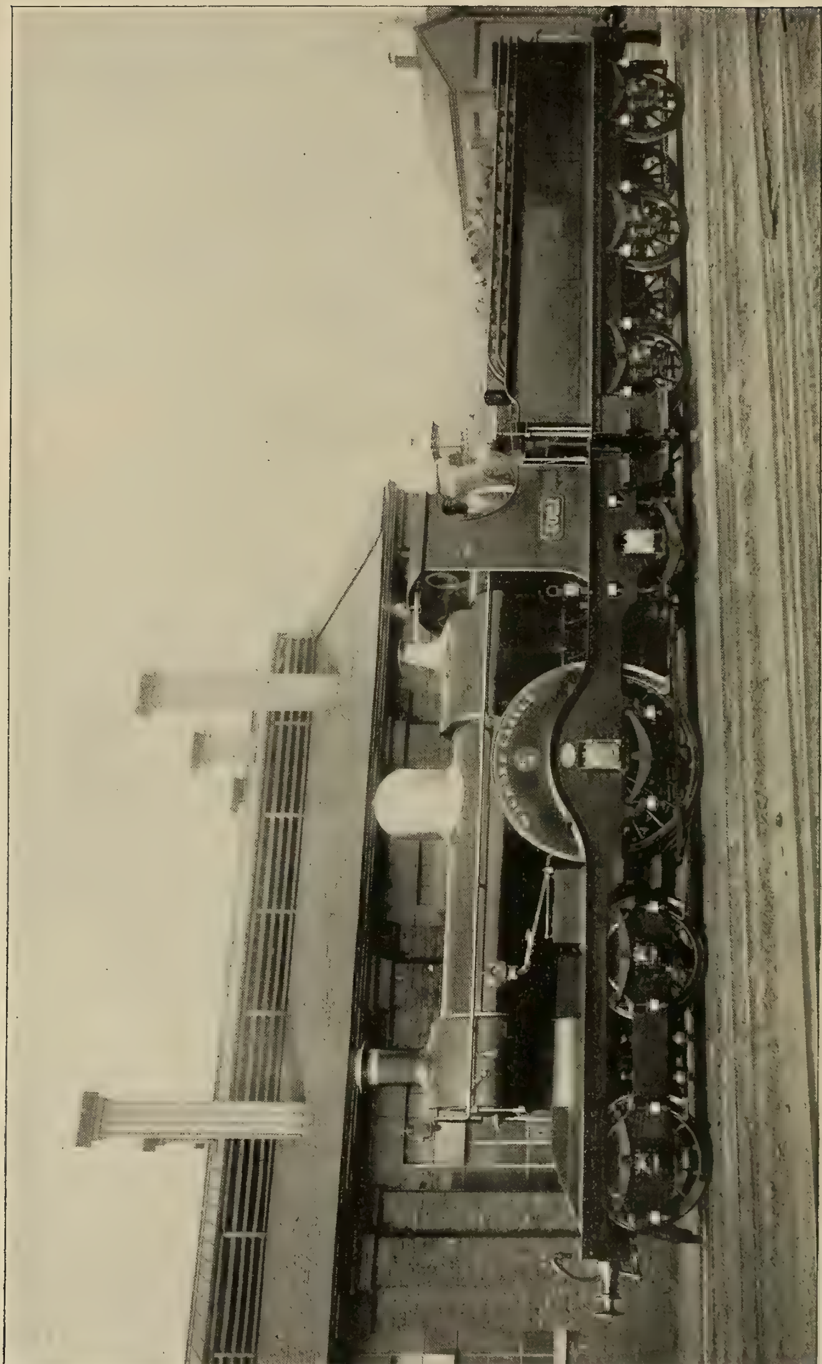
He began by experimenting with two classes of six-wheeled locomotives of exactly similar dimensions, except that the one had a single pair of 7-foot driving wheels and the other four 6-foot 6-inch wheels coupled, and as a result of exhaustive trials he was "led to believe that sufficient adhesion could be got with a single pair of driving wheels, whilst there was no doubt of the superiority of a single engine, in freedom and economy, over a coupled engine." However, in course of time the 7-foot single engine which he had adopted proved deficient in cylinder and adhesive power to deal with the growth of traffic, and accordingly he set about to design a larger and more powerful class.

These 8-foot wheel, outside cylinder, bogie engines were the result, and they have since been running at the head of the fastest and heaviest trains in the world with conspicuous success. As originally built, they weighed 38 tons 9 hundredweight, of which 15 tons were available for adhesion. The outside cylinders were, at the time, of unusual size, 18 inches by 28 inches, with an initial pressure of steam of 140 pounds per square inch to move the 8-foot 1-inch driving wheels. Inside a boiler barrel only 3 feet 9½ inches in diameter, were packed 217 tubes 1 9-16 inches in diameter, the total heating surface being, fire box (with sloping midfeather in place of brick arch), 122 square feet; tubes, 1043; total, 1165 square feet.

Engines of this type have, from the first, dealt with the heavy express traffic of the Great Northern Railway, taking loads of from eight to sixteen six-wheeled coaches (weighing about 15 tons each) with ease from King's Cross to Grantham, a distance of 105¼ miles, without a stop, at booked speeds of from 48 to 55 miles an hour, and from Grantham to York, Leeds and other Northern towns, over a road with a ruling gradient of 1 in 200. At the present time, there are fifty-three of these bogie engines at work, the latest differing from the first only in increased weight and power. Thus, No. 776, built in 1887, is officially announced as weighing 45 tons 14 hundredweight, 18 tons being on the drivers. The boiler carries 160 pounds of steam; a brick arch is substituted for the original water midfeath-

FROM A PHOTOGRAPH BY F. MOORE, LONDON.

THE GREAT NORTHERN LOCOMOTIVE "NO. 878,"



FROM A PHOTOGRAPH BY F. MOORE, LONDON.

THE "WIGMORE CASTLE" ON THE GREAT WESTERN RAILWAY.

er, and about half a dozen similar improvements of detail have been effected; otherwise the engine is practically identical with No. 53.

Two years ago Mr. Stirling built half a dozen of these bogie engines of still greater power, Nos. 1003 to 1007 having cylinders 19½ inches by 28 inches, and No. 1008, cylinders 19 inches by 28, the boiler pressure being 175 pounds. These engines weigh the large amount of 49 tons 11 hundredweight, with 19 tons 4 hundredweight on the driving wheels, and have a tender weighing 41 tons, 14 hundredweight, 2 quarters in working order, carrying 4000 gallons of water and 5 tons of coal, the whole moving mass being no less than 91 tons 5½ hundredweight. The illustration on page 36 shows No. 1008, one of these special engines. Despite their huge dimensions, however, they are barely modified copies of the first of the class, designed nearly thirty years ago. The general service of the whole class is given to the writer, by Mr. H. A. Ivatt, the present locomotive engineer, as between London and Leeds, at booked speeds up to 54 miles an hour between London and Doncaster, the longest distance run without a stop being from London to Newark, 120 miles. The average number of coaches is from twelve to fifteen, weighing 15 tons each, and the consumption of Yorkshire coal per train mile is officially put at from 30 to 35 pounds. With lighter trains of from 100 to 140 tons, during the railway race of 1888, the consumption of these engines was only 22.6 pounds per mile, though the actual running speeds were little, if any, short of 60 miles an hour. Engines of this class have been carefully timed at speeds of 84 miles an hour with a train.

About twelve years ago, however, while still adhering to his well known bogie type, Mr. Stirling placed on the Great Northern Railway a new class of six-wheeled singles, of which No. 878, shown on page 37, is an example. These engines are practically of the same standard of efficiency, with regard to fuel and capacity for dealing with fast, heavy traffic, as the larger bogie engines, and are cheaper in first cost. They have driving wheels 7 feet 7½ inches in diameter, driven by inside cylinders, 18½ inches by 26 inches, and have boilers similar in dimension to those of the No. 776 class. The latest of the class weigh 40 tons 13 hundredweight, with 17 tons 8 hundredweight on the drivers, and they are noteworthy on account of the great length of rigid wheel base, 19 feet 1 inch. An engine of this class, No. 233, took the East Coast racing train from London to Grantham on August 25, 1888, a distance of 105¼ miles, in 105 minutes, the load behind the tender being 100½ tons. The latest corridor train put on the Scottish service, with which the locomotives of these two classes will be called upon to deal, consists of eight twelve-wheeled bogie coaches, weighing 270 tons, with accomodation for 300 passengers. The general service on which these six-wheeled engines is engaged is practically the same as that of the bogie engines, with similar loads and a like expenditure of coal. Some time ago Mr. Stirling gave the consumption as 30.6 pounds per mile with trains averaging 177.6 tons at booked speeds of 50 miles an hour and upwards. It will be interesting to see whether Mr. Ivatt will perpetuate Mr. Stirling's types. He has already declared in favour of steam domes on the hitherto straight-backed boilers and has designed a handsome type of coupled bogie engine for express traffic, facts which seem to augur a gradual change from the hitherto prevailing practice of the Great Northern line.

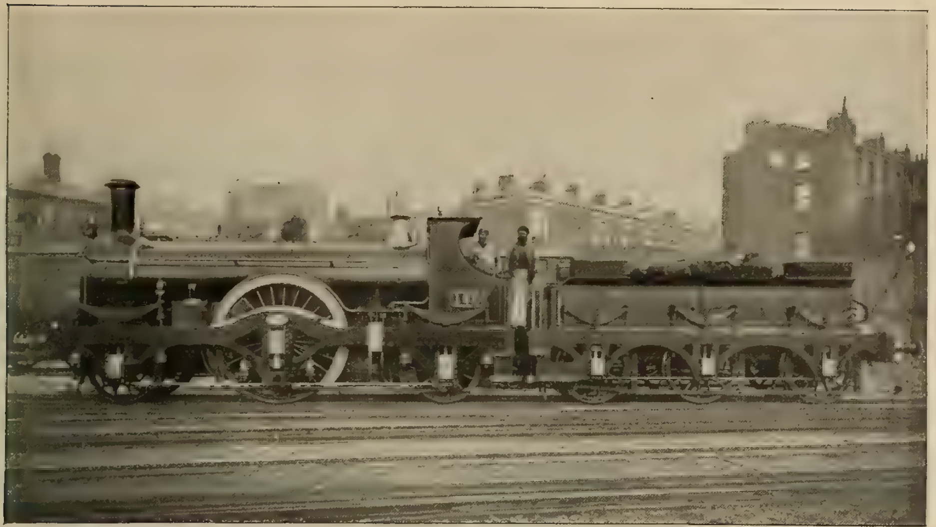
In 1874, Mr. William Stroudley designed a new type of single wheel engines for the London, Brighton and South Coast Railway, which has performed excellent service. The first engine of the class had driving wheels 6 feet 9 inches in diameter, but subsequent engines, to the number of twenty-five, had their wheels 3 inches smaller. They weigh about 33½ tons and have cylinders 17 inches in diameter with a 24-inch stroke. The illustration of the "Shanklin" on page 40, shows the leading characteristics of the class,

which are singularly neat and compact in form. A noteworthy feature is the employment of inside bearings to both engine and tender wheels. Stroudley's patent speed indicator is shown to be fitted, a pulley on the driving wheel being so geared as to raise the water in a gauge glass inside the cab to certain heights at given speeds. With the great increase in traffic to and from the South Coast, engines of the "Shanklin" class have been, to a great extent, superseded for the best express work in favour of more powerful front-coupled six-wheel engines, but they nevertheless still find plenty of employment in fast trains of lighter weight.

FROM A PHOTOGRAPH BY F. MOORE, LONDON.
THE LONDON, BRIGHTON AND SOUTH COAST RAILWAY EXPRESS LOCOMOTIVE "SHANKLIN."

On the Great Western Railway single drivers were almost exclusively employed for the broad gauge traffic between Paddington and Bristol, and the same principle largely prevailed also on the narrow gauge. In fact, until quite recently the standard narrow gauge express engine on that line was of the six wheeled type, having cylinders 17 or 18 inches in diameter, with a 24-inch stroke, and a pair of driving wheels 7 feet in diameter. A representative example of these useful locomotives is shown in No. 160, on page 41, which, with nine sister engines, was rebuilt in 1879 on to the framing of some previous engines first brought out in 1862. This framing is of the old broad gauge type, but other classes of single drivers presented a more modern appearance. Engines of this type weigh 33½ tons, 14 tons being available for adhesion, and they have a total heating surface, fire box and tubes, of 1278½ square feet.

Shortly before the abolition of the broad gauge in May, 1892, Mr. Dean, the present locomotive superintendent of the Great Western, designed some single-driving, six-wheeled engines of ingenious pattern. As originally built, they were placed on the 7-foot gauge, with the wheels ouside the frames, which were double on each side, and in that condition they ran with success until the order came to do away with the broad gauge. These engines, Nos. 3001 to 3030, then returned to the Swindon works, had new axles put to their wheels and reappeared on the narrow gauge, with their wheels between the double frames on either side. In this form, with cylinders measuring 20 inches by 24, single driving wheels 7 feet 8½ inches in diameter, and a total weight of 44 tons 4 hundredweight, they were a singularly handsome type of six wheeled engine.

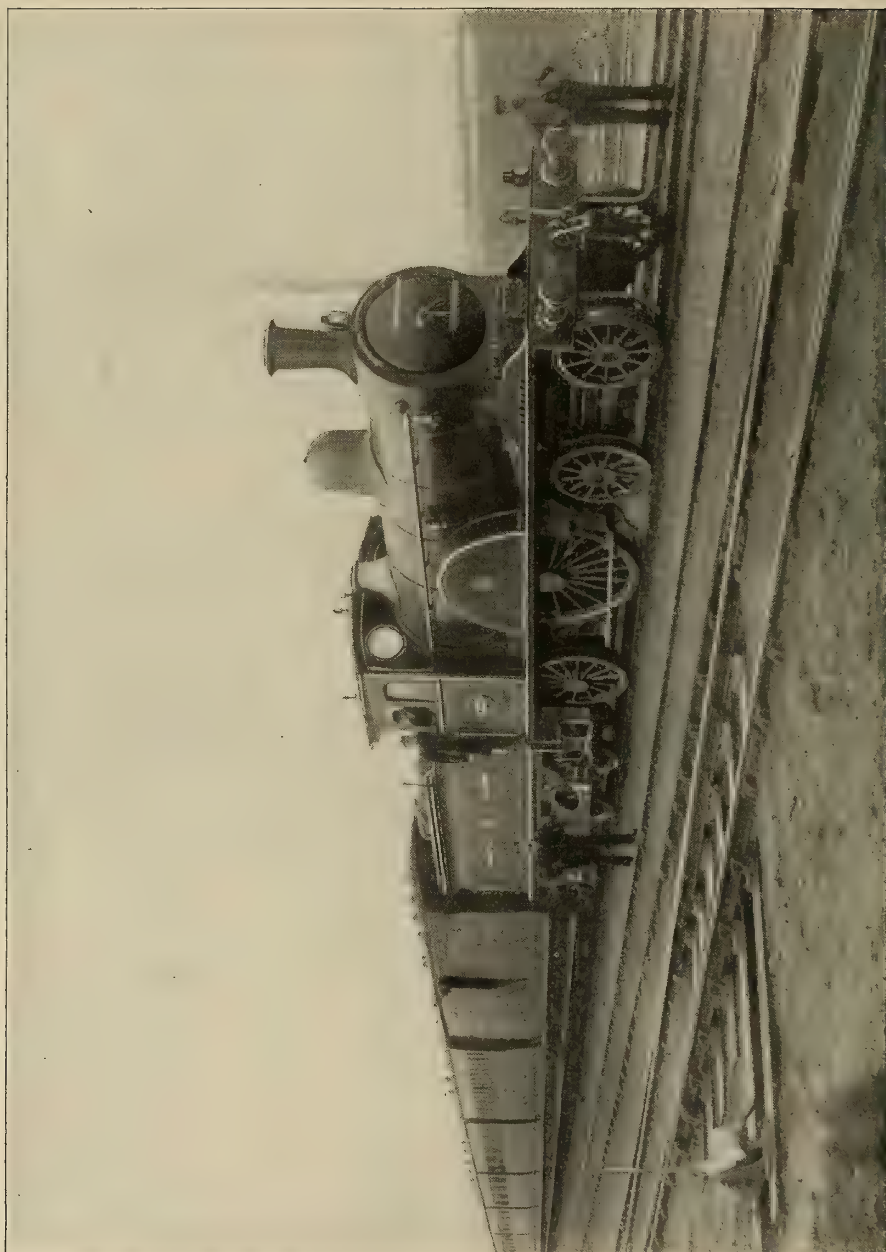


"NO. 160" ON THE GREAT WESTERN RAILWAY.

But a prolonged test showed them to have a peculiar see-saw motion in running, due to the great weight at each end, and they once more returned to the shops to have their frames cut and altered in front of the driving wheels, and a four-wheeled bogie placed under the smoke box in the place of the single pair of leading wheels. In their latest transformation they are probably the handsomest engines now running on British metals, as a glance at the illustration on page 38 of the "WigmoreCastle" will show. They now stand on a wheel base of 23 feet 6 inches, in place of the 18 feet 6 inches formerly existing, and their cylinders have been reduced in diameter to 19 inches. They weigh, in running order, 49 tons, of which 18 tons are on the driving wheels, and the boiler carries 16c pounds of steam and contains a total of 1445 square feet of heating surface.

A noteworthy feature is the return to the old raised fire-box. In addition to these transformed engines, a further batch of thirty bogie engines, identical in pattern save as to one or two details, and with 1561 square feet of heating surface, have made their appearance. Engines of this type run the "Dutchman," "Cornishman" and "Zulu" expresses of the Great Western line, and the South Wales trains, running without a stop from Paddington to Swindon, 77¼ miles, in 87 minutes; to Bristol, 118½ miles, in 135 minutes; to Bath, 106¾ miles, in 120 minutes; to Leamington, 106 miles, in 120 minutes; and from Newport to Paddington, 143¼ miles, in 177 minutes; and Paddington to Exeter, 194 miles, in 225 minutes; these two last being only possible by the adoption of Ramsbottom track tanks to replenish the tenders while running. Records like these, with heavy bogie coaches and corridor trains, speak well enough for the power of these successors of the old broad gauge eight-wheelers.

Mr. T. W. Worsdell, having transferred his services from the Great Eastern to the North Eastern Railway, proceeded to develop the Worsdell and von Borries system of compounding locomotives. His first engines of this type were of the four-coupled class, six wheelers, with a leading bogie, but in 1889 he put upon the metals five engines of the "1326" class, one of which, No. 1329, is shown at the head of a train on page 42. These are bogie engines of fine dimensions, having a pair of single driving wheels 7 feet 1¼ inches in diameter, and weighing 42



FROM A PHOTOGRAPH BY F. MOORE, LONDON.

THE NORTH EASTERN COMPOUND LOCOMOTIVE "NO. 1329."

tons, 17 hundredweight, 2 quarters in working order, of which weight 18 tons were placed on the driving wheels. There are two cylinders, one high-pressure, 18 inches by 24, and the other low-pressure, 26 inches by 24, both placed inside, between the frames immediately under the smoke box, and driving directly by means of an ordinary two-cranked axle. Engines of this class were designed to deal with trains of from thirteen to seventeen six-wheeled coaches on a service demanding speeds frequently exceeding 60 miles an hour, with the addition of a slightly larger fire box. One of them, No. 1518, attracted much attention in the engineering world by the wonderful feat of drawing a train weighing more than 223 tons, exclusive of engine and tender, at a speed of 86 miles an hour along the level, with an indicated horse-power of 1068. The average consumption of coal of No. 1517 during a series of severe trials, worked out to 26.4 pounds per mile.

Subsequently, Mr. Worsdell built still more powerful coupled bogie engines on the compound principle for the

FROM A PHOTOGRAPH BY F. MOORE, LONDON.

THE NORTH EASTERN "NO. 1517."

and the results of running seemed so satisfactory to their designer that, shortly afterwards, he brought out five engines of a still more powerful class, on the compound system, known as the "1517" class.

The illustration on this page shows one of these five engines as originally built, No. 1517 being put into work in October, 1889. These engines weighed 46 tons, 13 hundredweight, 2 quarters, with 17¾ tons on the driving wheels, and had cylinders of 20 inches and 28 inches diameter, respectively, and single driving wheels 7 feet 7¼ inches in diameter. Otherwise, they were practically of the same dimensions as the "1326" class, Scotch traffic, one class in particular weighing upwards of 51 tons, but these do not fall within the scope of the present article. On Mr. Worsdell's retirement from the North Eastern Railway, and the succession of his brother, Mr. Wilson Worsdell, to the same office, we find that the Worsdell and von Borries system of compounding is less in favour. The "1526" class appears to be relegated to fast local traffic, while the larger 7-foot 7¼-inch wheel single drivers have been rebuilt with two cylinders on the "simple" system, 19 inches by 24 inches, fitted with piston valves.

In 1879 Mr. Massey Bromley de-

British Express Locomotives, With Single-Driving Wheels.

	London and North Western.	Caledonian.	Great Northern.	London, Brighton and S. Coast.	Great Western.	Manchester, Sheffield and Lincoln.	Great Northern.	Caledonian.	Great Northern.	Midland.	Midland.	North Eastern.	North Eastern.	Great Eastern.	Great Eastern.	Great Northern.	Great Western.	Great Northern.
Built in year	1862	1862	1869	1874	1875	1884	1885	1886	1887	1888	1889	1889	1889	1879	1888	1892	1894	1894–5
Type:																		
Six-wheel or bogie	6-Wh.	6-Wh.	Bogie.	6-Wh.	6-Wh.	6-Wh.	6-Wh.	Bogie.	Bogie.	Bogie.	Bogie.	Bogie.	Bogie.	Bogie.	6-Wh.	6-Wh.	Bogie.	Bogie.
Cylinders:																		
Inside or outside	Outs.	Outs.	Outs.	Ins.	Ins.	Outs.	Ins.	Ins.	Outs.	Ins.	Ins.	Ins.	Ins.	Outs.	Ins.	Ins.	Ins.	Outs.
Diameter	16"	17¼"	18"	17"	18"	17½"	18½"	18"	18"	18"	18½"	18" 26"	20" 28"	18"	18"	18½"	19"	19½"
Stroke	24"	24"	28"	24"	24"	26"	26"	29'	28"	26"	26"	24"	24"	24"	24"	26"	24"	28"
Boiler:																		
Length	9' 4"	11' 6"	11' 5"	10' 5"	10' 6"	11' 6"	11' 5"	10' 3½"	11' 5"	10' 4"	10' 4"	10' 7"	10' 7"	11' 5¼"	10' 0"	11' 5"	11' 6"	11' 1"
Diameter	3' 10¾"	3' 10"	3'.9½"	4' 5"	4' 1⅛"	3' 11"	4' 2"	4' 3"	4' 0"	4' 0"	4' 0"	4' 3"	4' 3"	4' 1"	4' 2"	4' 0"	4' 3"	4' 0"
Height of centre above rails	6' 6⅝"	6' 8"	7' 1"	7' 3½"	7' 0"	6' 9"	7' 9"	7' 6"	7' 3¾"	7' 5"	------	7' 8"	7' 11"	6' 10"	7' 6"	7' 6"	7' 7¼"	------
Tubes.																		
Number	192	192	217	206	250	195	186	196	174	244	244	203	203	203	256	174	266	174
Diameter	1⅞"	1⅞"	1 9-16"	1¾"	1⅝"	1¾"	1¾'	1¾"	1¾"	242' 1⅝" 2' 1½"	242.1⅝" 2.1½"	1¾"	1¾"	1¾"	1⅝"	1¾"	1¾"	1¾"
Heating Surface:																		
Firebox	85	----	122	110	133	87	109	112	109	117	117	110	123	111	105.5	109	127.06	121.72
Tubes	1013	----	1043	1022	1145.5	1057	1001	973	936	1123.6	1123.6	1026.12	1016	1097	1124.96	936	1434.27	909.98
Total	1098	1172	1165	1132	1278.5	1144	1110	1085	1045	1240.6	1240.6	1136.12	1139	1208	1230.46	1045	1561.33	1031.70
Grate area	14.9	13.9	17.6	19.3	17.0	17.0	18.4	17.4	17.75	19.68	19.68	17.23	20.7	17.1	17 9	18.4	20.8	20.0
Diameter of																		
Leading or bogie wheels	3' 7½"	3' 8"	3' 11"	4' 6"	4' 0"	3' 8"	4' 1½"	3' 6"	3' 11"	3' 6"	3' 6"	3' 7¼"	3' 7¼"	4' 0"	4' 0"	4' 1½"	4' 0"	3' 11½"
Driving wheels	7' 7½"	8' 2"	8' 1"	6' 9"	7' 0"	7' 6"	7' 7½"	7' 0"	8' 1½"	7' 4"	7' 6"	7' 1¼"	7' 7¼"	7' 6"	7' 0"	7' 7½"	7' 8"	8' 1½"
Trailing wheels	3' 7½"	3' 8"	4' 1"	4' 6"	4' 0"	3' 8"	4' 1½"	4' 6"	4' 7½"	4' 2½"	4' 4"	4' 7¼"	4' 7¼"	4' 0"	4' 0"	4' 1½"	4' 6"	4' 7½"
Total wheel-base	15' 5"	15' 8"	22' 11"	15' 9"	17' 6"	15' 9"	19' 1"	21' 1"	22' 11"	21' 9½"	21' 9½"	21' 11"	21' 11"	23' 1"	16' 6"	19' 1"	23' 6"	23' 3"
Weight on																		
Leading or bogie wheels	9.8.0	9.5.0	15.0 0	10.8.0	10 0.0	11.3 0	11.18.0	13.10.0	17.11.0	14.13.2	14.10.1	14.12.0	15.18.2	17.5.0	13.5.2	12.4.0	18.0.0	19.12.0
Driving wheels	11.10.0	14.11.0	15.0.0	14.0.0	14.0.0	17.11.0	17.0.0	17.0.0	17.0.0	17.10.0	17.10.0	18.0.0	17.15.0	15.0.0	16.2.2	17.8.0	18.0.0	19 4.0
Trailing wheels	6.2.0	6.15.0	8.9.0	8.12.0	9.10.0	11.18.0	10.16.0	11.8.0	10.12.0	11.10.1	11.13.2	10.5.2	13.0.0	10.10.0	10.15.2	11.1.0	13.0.0	10.15.0
Total Weight of																		
Engine	27.0.0	30 13.0	38.9.0	33.0.0	33.10.0	40.12.0	39 14.0	41.18.0	45.3.0	43.13.3	43.13.3	42.17.2	46.13 2	42.15.0	40.3.2	40.13.0	49.0.0	49 11.0
Tender	17.10.0	------	26.10.0	------	26.10.0	22.8.0	33.7.3	33.10.0	33.7.3	------	37 0.0	33.16.0	40.1.0	------	------	40.5.3	32.10.0	41.13.0
Tender:																		
Capacity of tank, gallons	------	------	2700	2520	2600	3000	2900	2850	2900	------	3250	3038	3940	3000	------	3500	3000	4000
Coal, tons	------	------	3½	2	2	------	4	5	4	------	5	4	4	------	------	5	------	5

NOTE.—The weights and dimensions given in this table refer to the engines as originally built. Many of these have since been supplied with larger tenders, and in a few cases the engines themselves have undergone alterations affecting both weights and dimensions, particulars of which are given in the body of the article.

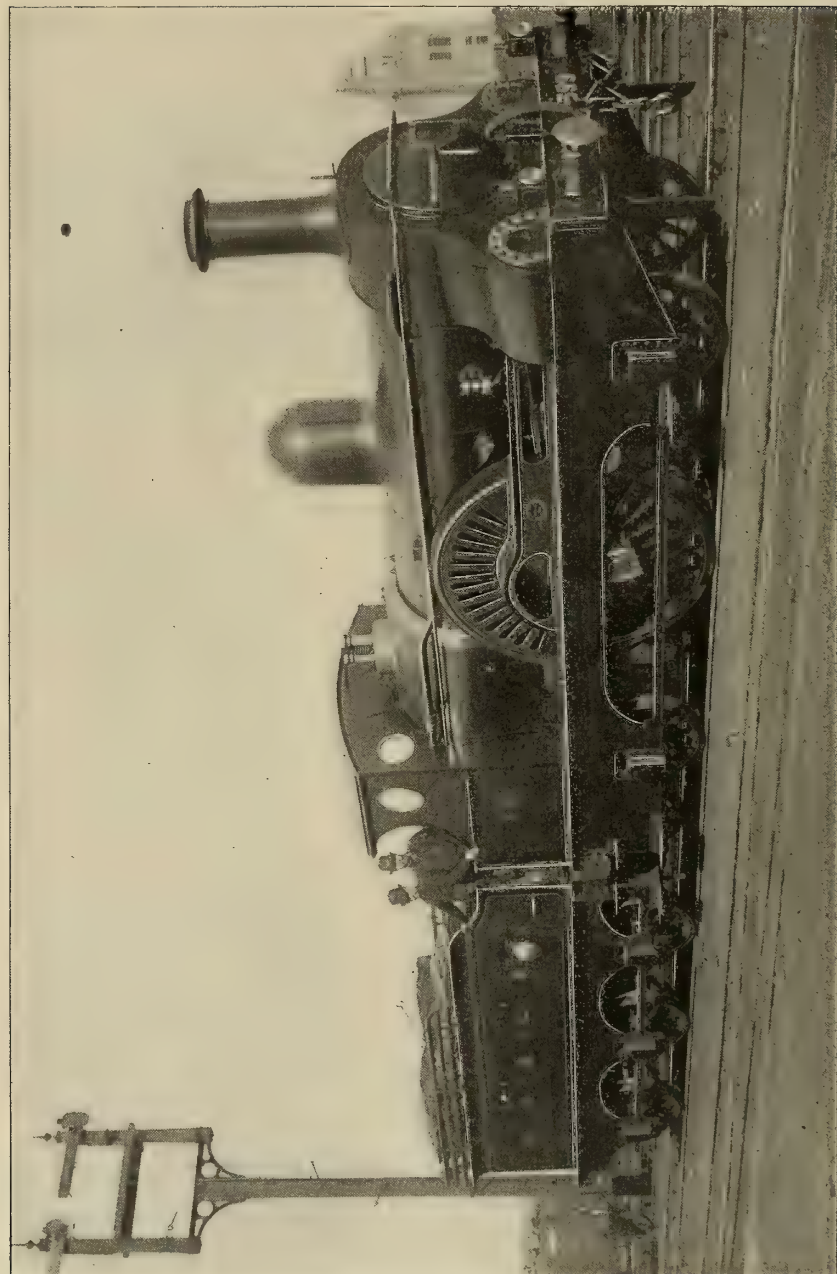
FROM A PHOTOGRAPH BY F. MOORE, LONDON.

THE GREAT EASTERN LOCOMOTIVE "NO. 771."

signed for the Great Eastern Railway the first of a series of twenty bogie single driving locomotives, somewhat similar to the famous 8-footers of the Great Northern. These weighed 42 tons 15 hundredweight, of which 15 tons were on the 7-foot 6-inch driving wheels. They had outside cylinders, 18 inches by 24 inches, and 1208 square feet of heating surface. They were useful engines of their type, but apparently inadequate to the growing traffic of the Great Eastern line, since they have not been renewed, the last of the series being "scrapped" in 1893. Henceforth, four-coupled engines seemed to be the leading specialty of the line until, in 1890, Mr. James Holden, the present locomotive superintendent, brought out a new class of six-wheeled single engines, of which No. 771, shown on this page, is a specimen. This type is practically the same as the standard four coupled class, with the exception that a pair of 4-foot wheels is substituted for the trailing pair of 7-foot coupled wheels, weighing 40 tons 3½ hundredweight in working order, of which 16 tons 2½

FROM A PHOTOGRAPH BY F. MOORE, LONDON.

MIDLAND RAILWAY EXPRESS LOCOMOTIVE NO. "1865."



FROM A PHOTOGRAPH BY F. MOORE, LONDON.

LOCOMOTIVE "NO. 399," ON THE MANCHESTER, SHEFFIELD AND LINCOLNSHIRE RAILWAY.

hundredweight are available for adhesion, with cylinders 18 inches by 24 inches, driving a pair of 7-foot wheels, and with ample heating surface. These have proved very successful engines for the fast services that have recently been instituted between London and various East Coast resorts.

There are at present twenty-one of these engines in work, the later ones weighing about 42 tons, the general service being between London and Cromer, and Cambridge and York, with an average of twelve coaches, weighing 176½ tons loaded, on a consumption of 31 pounds of coal per train mile. The fastest booked speed is between Tivetshall and Stowmarket, 20 miles, at 56.4 miles an hour, and the longest distance run without a stop is from Norwich to Liverpool Street, 115 miles. Six of the engines have recently been fitted with Holden's system for liquid fuel burning, and with water pick up tenders, in order to take part in the new service to Cromer, 138 miles in three hours, with only two stops. One of this class has accomplished the journey in 175½ minutes, by no means a despicable performance.

One of the fastest local services in the world is that run over the Cheshire Lines Committee's system between Liverpool and Manchester, a distance of 34 miles, which is accomplished by several trains in 40 minutes, and by a number in 45 minutes. The engines performing this service are supplied by the Manchester, Sheffield and Lincolnshire Railway Company, and are of the six wheeled, single-driving design originally introduced by Mr. Charles Sacré, of which No. 399, shown on the opposite page, is an example. As originally built, these engines weighed 40 tons, 12 hundred-weight, of which 17 tons, 11 hundred-weight were upon the drivers, and with their 7-foot 6-inch wheels, driven by cylinders 17½ inches by 26, and ample heating surface, they speedily acquired an enviable reputation for efficiency, being notably quick in getting up pace, a most desirable feature in so short a run. At the present time there are twelve of these fine locomotives in service, their weights having been altered to 38 tons, of which no less than 19 tons, 14 hundredweight are available for adhesion. Their load is six bogie coaches, weighing 180 tons, and their booked speed is 51 miles an hour. They accomplish their difficult task on an average consumption of 32 pounds of coal per mile.

Of all railway companies in the world the Midland would have seemed the least likely to revert, in its later years, to the single-driving locomotive. For upwards of twenty years the standard type of locomotive adopted on the line had been of the four-coupled pattern, with or without a leading bogie, and it seemed to be most improbable that this pattern, which had proved so successful, should ever be departed from. However, the introduction of Messrs. Holt and Craven's steam sanding appliance for locomotive driving wheels so far altered the condition of things that, in 1887, after conducting a course of experiments with a coupled engine of which the side rods had been removed to convert it into a single-driver, Mr. S. W. Johnson, the locomotive superintendent of the company, brought out his famous class of single-driving bogie engines, the success of which has never since been questioned. The first of these, known as the "26" class, had wheels 7 feet 4 inches in diameter, driven by inside cylinders, 18 inches in diameter with a 26-inch stroke, and weighed, in working order, 43 tons, 13 hundredweight, 3 quarters, of which 17½ tons were allotted to the drivers.

Subsequent engines, of which No. 1865, shown on page 45, is an example, had 7-foot 6-inch driving wheels, and cylinders 18½ inches by 26, the latest having cylinders 19 inches by 26. There are about seventy of these now in use on the fastest express work of the line, conveying trains of from 170 to 215 tons at booked speeds of 53½ miles an hour, and traversing, without intermediate stops, the 124 miles lying between St. Pancras, London, and Nottingham. Their consumption of coal averages from 20 to 23 pounds per mile. At the time of writing Mr. Johnson has brought out

a still larger class of the same pattern, with 19½-inch by 26-inch cylinders, and 7-foot 9-inch driving wheels, which is, at present, on trial.

It may be instructive to give a condensed table (see page 44) showing the comparative dimensions of all the single-driving locomotives mentioned in the foregoing brief account. American engineers, seeing them for the first time, will probably be surprised at some of the figures, when gauging the work done by these comparatively small engines on a consumption of coal averaging between 21 or 22 and 30 pounds per mile with similar work done in the United States by much larger and heavier machines on a consumption of nearly double that amount of coal per mile. Further into this debatable ground it is not the intention of the writer to trespass at the present moment. There may be differences of method obtaining on either side of the Atlantic which render a true comparison impossible. Be that as it may, the object of this article will be served if it tends to draw attention to the fact that on British railways there are, in addition to a number of fine coupled engines, a collection of single-driving locomotives of superlative excellence and maximum efficiency, which perform the duties allotted to them with unfailing regularity and with economical results that cannot be matched when the tasks that they are called upon to execute are duly taken into consideration.

ANHYDROUS AMMONIA FOR ICE MACHINES.

By Henry Faurot.

A paper recently read before the Southern Ice Exchange.

AMMONIA, under ordinary conditions, is a colourless gas, consisting of a combination, or union, of two other gases, nitrogen and hydrogen, in the proportion of one part of nitrogen to three parts of hydrogen by measure. Under ordinary conditions of temperature and atmospheric pressure, as stated, it is a gas; yet at a temperature of 40 degrees below zero, at normal atmospheric pressure, or when it is subjected to 100 pounds pressure per square inch at ordinary temperature, it becomes liquid; while at about 110 degrees below zero it congeals or freezes to a white, crystalline, odourless mass, becoming chemically inert and not showing any of the affinities or characteristics which belong to it while in a liquid or gaseous state. The boiling point of liquid ammonia varies with different observers all the way from 40 degrees to 30 degrees below zero F.

Ammonia gas, when pure, is not combustible; it burns only when mixed with air or oxygen, and then with explosive force. It is said that ammonia decomposes slowly when subjected to a heat of about 212 degrees F.; faster at a higher temperature, and at about 800 degrees F., it rapidly and almost instantly separates into its component gases of nitrogen and hydrogen.

Ammonia gas is readily soluble in water, one volume of water dissolving at 32 degrees F. about 1148 times its volume of ammonia gas, and at an ordinary temperature about 730 times its volume.

In the operation of ice and refrigerating machinery, the quality of the anhydrous ammonia used is of great importance, and the best results are attainable only when pure ammonia is used. To buy as cheaply as possible is good business sagacity when quality has its proper share of consideration, but poor ammonia, whatever the price, is the most costly article about an ice or refrigerating plant. If, in purchasing a cheap or

low grade ammonia, one were to lose only the percentage of impurity it might contain, the hardship would not be serious.

To illustrate:—Suppose one buys a barrel of oil containing 3 per cent. of water. Here 97 per cent. of pure oil would have full value, the only loss the buyer sustains being the price paid for 3 per cent. of valueless substance. This cannot apply to liquid ammonia, for the mere presence of a small percentage of impurity is not only a loss in itself, but by its presence affects and depreciates the working value of the bulk of pure ammonia, rendering the whole of lower grade.

It is a well-known law in chemistry that most liquids, when chemically pure, have a fixed boiling point. The addition of any substance or impurity raises or lowers this boiling point, and in liquid anhydrous ammonia it raises it, which means that ammonia boils, or "expands," at a higher temperature; and, as the purpose of a refrigerating or an ice making plant is the low temperatures, or "cold," produced by evaporation, boiling or expansion of the liquid ammonia in the expansion of brine tank pipes, it is evident that the best or cheapest ammonia, in the end, is that which boils or expands at the lowest temperature; in other words, the purest.

This refrigerating effect is not the only one to be considered, as the purer the ammonia, the less power it takes to compress it to a liquid, and power in this case means a good deal of money expended. It means the cost of operating the engine and boiler rooms, the cost of coal, water, oil, machinery, wages, and other items.

Another and most important source of loss caused by the use of impure ammonia is the greater liability to disintegration than that of the pure; for, as everybody knows, impure substances are more likely to decay or spoil than those that are pure. This applies even to substances at rest, while in the cycle of operation in a refrigerating plant, the ammonia is continually undergoing the most extreme conditions of heat and cold, compression and expansion, and a probable electrical excitement through friction of machinery, etc.; all of which are aids in hastening any predisposed tendency to disintegration.

The substances usually making up the impurities in anhydrous ammonia are foreign gases, oils, water, mineral matter and salts of ammonia. Foreign gases consist partly of air, due to defective packing of the piston rod of the compressor, but mainly of methane (commonly called marsh gas), ethene, acetylene, carbon monoxide, carbon dioxide, propylene, vapours of benzol, toluol and ethane, sulphureted hydrogen, etc., some of them being inflammable and explosive.

When these gases find their way into a refrigerating system, owing to the much higher condenser pressure necessary for their liquefaction than is required to condense pure ammonia gas, they greatly increase the power necessary for proper compression. Furthermore, methane and other inflammable gases, by the high heat of compression which they cause, readily decompose, and in so doing greatly assist the decomposition of the otherwise stable ammonia; and should there be any air or oxygen in the system, would possibly cause the violent explosions which happen now and then, and for which no positive explanation has as yet been agreed upon. However, I am of the opinion that the above named gases are not infrequently the cause of these explosions. All these decomposed and foreign gases are commonly known as "air" or "foul gases," and an idea may be easily formed of the enormous loss of power due to their presence from the fact that decomposed ammonia—that is, nitrogen and hydrogen—furnishes only about 8.7 per cent. of the refrigerating effect that pure ammonia furnishes. In other words, they require over eleven times more power to produce a given refrigerating effect than they do when combined as ammonia.

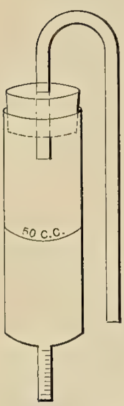
Upon evaporating impure liquid ammonia, a pale yellowish fluid remains behind, which is generally called the "water" of ammonia. This consists partly of heavy mineral oil, which is

detrimental, as it works its way into the expansion pipes, forming a non-conducting coating on the inside; and also consists principally of some of the different varieties of alcohol—methyl, ethyl, propyl, etc.—and other liquid compounds, all of which are highly inflammable and decompose easily.

Other impurities are water, mineral matter and salts of ammonia, which quite often attack the working parts of the machinery or clog the valves of the system.

The pipes and system in which ammonia is used should be thoroughly clean, as pure ammonia in a dirty system will work as badly as impure ammonia in a clean one.

Ammonia should be tested not only for the protection of the buyer, but for the protection of the seller as well. There are many devices for testing anhydrous ammonia, but it is my purpose to submit only a few easy and convenient methods that any engineer can employ, and while they are not calculated to demonstrate with the nicety of an exhaustive laboratory analysis, they will answer all practical purposes. To determine liquid residues I use a glass tube about 6½ inches deep and 1⅛ inches in diameter, and drawn out to a narrow tube at the bottom. The capacity of this tube is 100 cubic centimeters, and the narrow bottom is divided or graduated into cubic centimeters and fractions thereof. The top is supplied with a rubber cork having a vent tube of glass, the outer portion of the vent tube being bent down close to the large tube in such a manner that the whole may be placed in a glass of water. To convey ammonia from the cylinder into the tube a short iron pipe should be screwed into the cylinder valve. Open the valve and allow enough ammonia to run out to thoroughly cleanse the valve and pipe of any rust or other impurities that may have accumulated in them. Then let the ammonia flow into the tube until it is half full; adjust the cork and set the large tube into a glass of water, placing another glass of water beside the first to receive the vent tube. As the ammonia boils, the gas passes off through the vent tube and is absorbed by the water in the glass. Care must be exercised to remove the vent tube from the water toward the end of the operation, and allow the last part of the ammonia to evaporate into the air, otherwise the water will be sucked into the tube and thereby spoil the test. The residue, if any remains, can be easily read through the graduated scale. If a quicker evaporation is desired, it can be obtained by placing both tubes in one glass of water. The test tube should be carefully cleaned, and wiped perfectly dry before using.



AMMONIA TEST TUBE.

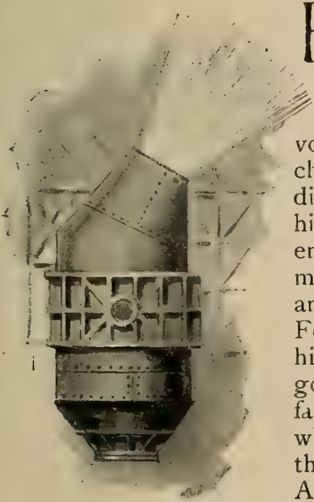
To test for inflammable gases, have the iron pipe bent in such a manner that the ammonia can be discharged into the bottom of a pail of cold water. Submerge over the mouth of the pipe a glass funnel, having the end tightly corked. Allow the ammonia to flow in a small stream. The ammonia gas will be absorbed by the water, while the other gases will rise to the top of the funnel, and if methane or other inflammable gases are present, they will, if released and lighted with a match, burn with a blue flame.

To test for boiling point, draw off about six to eight ounces of liquid ammonia into a cylindrical shaped glass or chemical beaker. Place this on a wet iron plate or surround it with water, and when it boils insert into it the bulb only of a special low standard chemical thermometer, reading off through the walls of the glass, and observing the temperature when the mercury remains stationary, as the boiling point. Commercially pure liquid ammonia should boil at not higher than 28.6 degrees below zero F.; lower temperatures denote purer ammonia, while a less pure ammonia boils at a higher temperature. In testing for the boiling point, the thermometer should be held as stationary as possible, and not moved about in the liquid.

ANDREW CARNEGIE.

A Biographical Sketch of a Great Industrial Engineer.

By John Denison Champlin.



HE who forces his way to the front among men, and achieves prominence in his vocation must have characteristics that distinguish him above his fellows. It is not enough to say that a man has won fame and wealth because Fortune has favoured him. When the blind goddess showers her favours, they are few who are able to avail themselves of them. All may hold with the bard that

> "There is a tide in the affairs of men
> Which, taken at the flood, leads on to fortune,"

but it is only the man of quick perception, of keen foresight, of persistent will and perseverance, who is ready to launch his bark upon that favouring tide, and able to steer it safely into the haven of success.

If there ever was a man more capable than most of his fellows of recognising and of seizing opportunity, that man is the subject of this sketch. His career from his youth up has been phenomenal in this respect. With a keen discrimination, born usually of long experience, but with him a matter largely of intuition, he has selected the best of Fortune's favours when many were within his grasp, and the result has always proved the wisdom of his choice.

He has shown the same wise perception in his judgment of men. In all his undertakings he has associated with himself not only men of worth and capacity, but men capable of carrying into execution his manifold ideas, thus virtually making his brain many-handed. All this, coupled with an unflinching integrity and a keen sense of honour derived from a reputable ancestry, has made him what he is,—one of the foremost men of his time in business, in philanthropy, and in all that tends to benefit his fellow man.

Andrew Carnegie was born on November 25, 1837, in the ancient burgh of Dunfermline, Fifeshire, Scotland, thirteen miles from Edinburgh,—a place famous as the home of the Scottish kings until Malcolm Canmore ventured across the Frith of Forth and planted his standard on Edinburgh's rock. After that it became the royal burial place and there, in the ancient Abbey Church, Robert the Bruce was laid in his winding-sheet of cloth of gold five centuries before this Scottish-American boy saw the light. There, too, in the palace whose ruined walls are still to be seen, hard by the Abbey Church, was born the unfortunate Charles I., doomed to be stripped of his royalties by the people whose liberties and rights he had outraged.

In the shadow of these and of other memories Andrew Carnegie grew up to revere the historic past of his native land, and to love her heathered hills; but his veneration was coupled with a hatred of feudal institutions, that has made him to-day a democrat of democrats.

Mr. Carnegie owes much to his parentage. His father, William Carnegie, a master linen weaver before the days of steam was a man of rugged character, a radical in politics, and a born reformer. With the strongest of political convic-

tions, he combined the power of giving them expression, and he had a local reputation both as a writer and a speaker. To him are largely due his son's radical notions of equality, and that superb faith in republican institutions which has blossomed into "Triumphant Democracy."

Mr. Carnegie relates with pride that among his earliest recollections is that when a mere child he once wandered into a public hall in Dunfermline and was surprised to find his father there,

CARNEGIE'S BIRTHPLACE AT DUNFERMLINE, SCOTLAND.

making a political speech. To his mother he owes an even greater debt of gratitude. She was a remarkable woman of fine temperament, and of great force of character, united with a strength of will and of determination fitted to overcome obstacles. She was her children's only teacher until Andrew was eight years old, when he was placed at school under a Mr. Martin, a noted teacher in Dunfermline, under whose care the boy soon became an apt scholar.

The introduction of steam machinery and of the factory system brought about a change in the fortunes of the Carnegie family. William Carnegie, who, with his four looms and his apprentices, had made a respectable living by supplying the merchants with hand-woven linens, found his occupation gone and was obliged to look elsewhere for means of support. His thoughts were turned towards the United States by the reports of relatives already settled in Pittsburg, and in 1848 he and his wife resolved to emigrate thither. It was a great sacrifice for them; but with a spirit of self-abnegation characteristic of their lives they said,—"It will be better for the boys." The family, consisting of the father, mother, Andrew and a younger brother Thomas (always associated with Andrew, but who died early), crossed the ocean in a sailing vessel and went to Allegheny City, then a town of about 10,000 inhabitants, opposite Pittsburgh. There Andrew found his first employment, when twelve years old, as a bobbin boy in a cotton factory at one dollar and twenty cents a week. Before he was thirteen he had learned to run a steam engine and was employed as engineman in a factory for making bobbins. His next step in advancement was to the clerkship of his employer, who had found out that the boy could write a good hand and knew something about arithmetic. But this was in addition to much hard labour elsewhere in the factory, and by no means satisfied his youthful ambition, which had, even then, begun to look into the future.

One day, when fourteen years old, he applied for a position in the office of the Ohio Telegraph Company, and was employed as a messenger boy at $2.50 a week. Of this episode in his career Mr. Carnegie himself writes:—

"My entrance into the telegraph office was a transition from darkness to light—from firing a small engine in a dark and dirty cellar into a clean office with bright windows and a literary at-

mosphere, with books, newspapers, pens, and pencils all around me. I was the happiest boy alive."

Mr. James D. Reid, the superintendent of the office, and himself a Scotchman, favoured the ambitious lad and helped him. In his "History of the Telegraph" he says of him:—

"I liked the boy's looks, and it was easy to see that, though he was little, he was full of spirit. He had not been with me a month when he began to ask whether I would teach him to telegraph. I began to instruct him and found him an apt pupil. He spent all his spare time in practice, sending and receiving by sound and not by tape, as was largely the custom in those days. Pretty soon he could do as well as I could at the key, and then his ambition carried him away beyond doing the drudgery of messenger work."

The death of his father at this time threw the burthen of the support of the family on the boy's shoulders, for his brother was yet too young to aid him; but he did not flinch from the ordeal. He became an operator in the telegraph office at $25 a month,—a sum which seemed to him then a fortune, for on it the family could be independent. He earned a little additional money by copying telegraphic messages for the newspapers, and was now on the road to success.

The *Electric Age* said of this period of his career:—"He was a telegraph operator abreast of older and experienced men; and, although receiving message by sound was, at that time, forbidden by authority as being unsafe, young Carnegie quickly acquired the art, and he can still stand behind the ticker and understand its tongue. As an operator he delighted in full employment and the prompt discharge of business, and a big day's work was his chief pleasure.

"And so it happened that when the Pennsylvania Railroad Company needed an operator 'Andie' was at once chosen to fill the place. Here he first developed those peculiar qualities of mental acumen and intuition which have since made him the manager of men and the director of broad and useful enterprises. He soon mastered the details of dispatching, and showed how the telegraph could be made to minister to railroad safety and success."

His marked ability soon led to his appointment as secretary to Colonel Thomas A. Scott, then superintendent, and to his removal to the headquarters of the company, and not long afterward, when Colonel Scott became vice-president, to his advancement to the responsible duties of superintendent of the Western division of the Pennsylvania railroad.

One day, when Mr. Carnegie was on a train examining the line from the rear window of a car, a tall spare man accosted him and asked him to look at an invention he had made. He drew from a green bag a small model of a sleeping berth for railway cars, and proceeded to point out its advantages. It was Mr. T. T. Woodruff, the inventor of the sleeping car. Mr. Carnegie tells the story himself in "Triumphant Democracy":—

"He had not spoken a minute before, like a flash, the whole range of the discovery burst upon me. 'Yes,' I said, 'that is something which this continent must have.'

"Upon my return I laid it before Mr. Scott, declaring that it was one of the inventions of the age. He remarked:—'You are enthusiastic, young man, but you may ask the inventor to come and let me see it.' I did so, and arrangements were made to build two trial cars, and run them on the Pennsylvania railroad. I was offered an interest in the venture, which, of course, I gladly accepted. * * *

"The notice came that my share of the first payment was $217.50. How well I remember the exact sum! But two hundred and seventeen dollars and a half were as far beyond my means as if it had been millions. I was earning $50 per month, however, and had prospects, or at least I always felt that I had. I decided to call on the local banker and boldly ask him to advance the sum upon my interest in the affair. He put his hand on my shoulder and

said:—'Why, of course, Andie, you are all right. Go ahead! Here is the money.'

"It is a proud day for a man when he pays his last note, but not to be named in comparison with the day in which he makes his first one, and gets a banker to take it. I have tried both and I know. The cars paid the subsequent payments from their earnings. I paid my first note from my savings, so much per month, and thus did I get my foot upon fortune's ladder. It is easy to climb after that. And thus came sleeping cars into the world," which, under the able management of Mr. George M. Pullman, have since achieved so great a success.

When the American Civil War broke out in 1861 Mr. Carnegie was called to Washington by Colonel Scott, who was then Assistant Secretary of War, and entrusted with the charge of the military railroads and telegraphs of the Government. As railway communication with the capital had been broken, Mr. Carnegie had to go by water from Philadelphia to Annapolis, where he began, with a large force, to repair the line in order to open communication with the seat of government.

General Butler, with the Massachusetts troops, had arrived meanwhile at Annapolis and was encamped there, awaiting the opening of the line. Carnegie rode into Washington on the first locomotive that went over the road. Between Elbridge Junction and Washington the Confederates had pinned the telegraph wires to the ground so as to interrupt communication. Carnegie, observing this in passing, stopped the train and jumping off the engine proceeded to release the wires. The first one loosened bounded up and cut a severe gash in his cheek, and he entered the city bleeding profusely. So far as is known, he was the third man injured in the war in the service of the Union, two soldiers having been hurt a few days before while passing through Baltimore.

At the battle of Bull Run Carnegie was on the field in charge of the railway communication, and was the last official to leave for Alexandria. As an attack upon Alexandria was expected during the night, many of the railway staff escaped across the Potomac and much difficulty was experienced in manning the trains next morning.

Another commercial enterprise into which Mr. Carnegie entered shortly afterward turned out still more advantageously. In company with several others, he purchased the now famous Storey Farm on Oil Creek, Pa., where a well had been bored and natural oil struck the year before. Mr. Carnegie can best tell this story in his own words. The writer quotes again from "Triumphant Democracy":—

"When I first visited this famous well the oil was running into the creek where a few flat bottomed scows lay filled with it, ready to be floated down to the Allegheny river upon an agreed-upon day each week, when the creek was flooded by means of a temporary dam. This was the beginning of the natural oil business. We purchased the farm for $40,000, and so small was our faith in the ability of the earth to yield for any considerable time the hundred barrels per day which the property was then producing, that we decided to make a pond capable of holding one hundred thousand barrels of oil, which, we estimated, would be worth, when the supply ceased, $1,000,000.

"Unfortunately for us the pond leaked fearfully; evaporation also caused much loss, but we continued to run oil in to make the losses good, day after day, until several hundred thousand barrels had gone in this fashion. Our experience with the farm may be worth reciting. Its value rose to $5,000,000; that is, the shares of the company sold in the market upon this basis, and one year it paid in cash dividends of $1,000,000,—rather a good return upon an investment of forty thousand dollars."

But Carnegie was not satisfied with these enterprises, and was soon busy with other industrial conquests. Railway bridges were then built almost exclusively of wood, but the Pennsylvania railroad, always foremost in improvements, had begun to experiment with

cast iron for bridge building. Carnegie, recognising that the railway bridge of the future was to be of iron, organised in Pittsburgh a company for the construction of iron bridges,—the first step on the road to the pre-eminence that he has attained as the largest iron and steel master in the world.

The Keystone Bridge Works, thus established, were remunerative from the beginning, and built the first iron bridge across the Ohio river. The Union Iron Mills soon followed, and later the now famous Edgar Thomson steel rail mill. The last was the outcome of a visit to England in 1868, when Carnegie noticed that English railways were discarding iron for steel rails. The Bessemer process had then been perfected, and was making its way in all the iron producing countries. Carnegie, recognising that it was destined to revolutionise the iron business, introduced it into his mills and made steel rails with which he was enabled to compete with English manufacturers.

His next enterprise was the purchase of the Homestead Steel Works,—his great rival at Pittsburgh. By 1888 he had built or acquired seven distinct iron and steel works, all of which are now included in the Carnegie Steel Company, Limited. All the plants of this great firm are within a radius of five miles of Pittsburg. In probably no other part of the world can be found such an aggregation of splendidly equipped steel works as those controlled by this association, which now comprise the Homestead Steel Works, the Edgar Thomson Steel Works and Furnaces, the Duquesne Steel Works and Furnaces, all within two miles of each other; the Lucy Furnaces, the Keystone Bridge Works, the Upper Union Rolling Mills, and the Lower Union Rolling Mills.

First in importance among these are the great Homestead Works, where are manufactured the armour plates for the ships of the United States Navy, and all kinds of structural material. Here are twenty open-hearth furnaces and two ten-ton Bessemer converters, and every working day sees turned out 3000 tons of steel ingots, all of which are finished and manufactured into a great variety of forms, from the steel rim of the bicycle to the armour plate of 200 tons, and shipped to all parts of the United States and to foreign countries as well. Here, too, are constructed the great steel frames for many of the buildings that tower skyward in all the larger American cities. Ordinarily the construction of one of the largest of these immense buildings does not require more than a week's work for one department of the Homestead Steel Works. The men, of whom 3500 are employed, are mostly skilled workmen, because the class of work produced is exceptionally high, and the average wages per man are the highest paid in the world.

Electricity plays an important part at these works in handling heavy masses and in assembling and arranging the small parts of a great structure. Masses weighing 200 tons are handled with ease by the electric machines, all of which are operated from a single station, whence the wires extend to all the buildings. So accustomed have the workmen become to the use of the electric agent that they speak of ampères, volts, etc., with almost as much familiarity as they used to of steam and water power.

Next in importance to the Homestead Works are the Edgar Thomson Steel Works and Furnaces, which are devoted to the production of pig iron and to the manufacture of rails. The furnaces have a daily output of 2800 tons of pig iron, a large part of which is consumed here; the remainder is shipped to Homestead. The mills have a capacity of 1600 tons of steel rails per day.

The Duquesne Steel Works and Furnaces have four large blast furnaces, among the most modern and best equipped in the world, and manufacture daily 2000 tons of pig iron into billets, rails, sheet bars, splice bars, etc. The Upper Union Mills, the Keystone Bridge Works, and the Lower Union Mills are devoted to the manufacture of specialties in iron and steel.

In the aggregate, the Carnegie Steel Company can produce, monthly, 140,-

THE EDGAR THOMSON STEEL WORKS AND BLAST FURNACES AT BESSEMER, PA.

000 tons of pig iron and 160,000 tons of steel ingots. About one hundred locomotives, standard and narrow gauge, are used in moving material about its various yards. In its steel industries alone about 15,000 men are employed, to say nothing of the great number in the coke works, mines, transportation, etc., which swell the total to about 25,000. The monthly pay roll exceeds $1,125,000, or nearly $50,000 for each working day. Including the Frick Coke Company the united capital of the Carnegie Steel Company exceeds $60,000,000.

The Frick Coke Company, one of several establishments in which the Carnegie company is interested, is the largest in the world. The Frick company have 10,500 ovens and make more than 15,000 tons per day, on some days shipping nearly 20,000 tons, and requiring more than five miles of railway cars to move the product. The company owns more than 40,000 acres of coal lands or more than two-thirds of the celebrated Connellsville coal field.

To build up this immense business within a single generation, and to shape its destinies so successfully as to make it not only the equal, but the superior, of all similar industries on the globe, is a feat of which any man might be proud and which few men have the capacity to accomplish. That Mr. Carnegie has accomplished it is a proof not only that he possesses a phenomenal business capacity, but also that he is a born ruler of men. I have often heard him say that the man who succeeds best in the world is he who knows how to avail himself of the labour of other men. In this Mr. Carnegie is pre-eminent. His fine instincts and keen judgment enable him to see at a glance, and in their true perspective, the capacities and capabilities of both men and things. He seems to see intuitively what a man can do, and he thoroughly trusts every man whom he employs.

Mr. Carnegie is a strong advocate of the payment of labour on a sliding scale, based upon the prices obtained for the products manufactured. This system, which he introduced seven years ago, has worked to the entire satisfaction of the men and the company. The workmen, Mr. Carnegie explains, are thus made partners in the business without risk to themselves, being always sure of at least moderate wages, as a minimum wage is provided for, and always certain to share promptly with the firm in any advance of prices. The business correspondence of the firm is laid every month before a committee appointed by the men themselves, and these representatives of the working force, after due examination, strike an average which forms the basis for the ensuing month.

To induce them to save, every workman is allowed to deposit part of his savings, not exceeding $2000, with the firm, on which the high interest rate of 6 per cent. is allowed. The firm also lends to any of its workmen money to buy a lot or to build a house, taking its payment by installments. With the exception of a strike at the Homestead Works, there has never been any serious difference between the firm and its men.

Mr. Carnegie attributes the success of his several concerns to the policy he has adopted of giving a personal interest to men who render exceptional service. There are many such, and every year several more are added to the list of partners. It is the policy of the company to interest every superintendent of works, every head of a department, every exceptional young man. Promotion follows exceptional service and there is no favouritism.

"My partners," says Mr. Carnegie, "are not only partners, but a band of devoted friends who never have a difference. I have never had to exercise my power, and of this I am very proud. Nothing is done without a unanimous vote, and I am not even a manager or director. I throw the responsibility upon others and allow them full swing."

Although Mr. Carnegie is "not even a manager or director," his judgment is largely depended upon for the solution of questions that require sagacity and foresight, and he is frequently consulted by his fellow partners, usually by

telegraph, as he is no longer a resident of Pittsburgh. Every day, in whatever part of the world he may be, a tabulated form carefully filled up, giving the product and details of every department of the works, is mailed to him, thus enabling him to keep thoroughly in touch with his business.

Notwithstanding the drain upon his time and energies, involved in the building up and prosecution of such immense enterprises, Mr. Carnegie has found leisure to indulge in literary work. In this, in which he takes great pleasure as a relaxation from business cares, he has won an enviable reputation, and articles from his pen are welcomed by the principal periodicals, both in the United States and in England.

His first book, entitled "Round the World," which appeared in 1879, contained a sketchy and characteristic account of a trip across the Pacific Ocean to Japan, China, and India and home again via the Suez Canal and Europe. It was followed, in 1882, by a volume entitled "Our Coaching Trip," an account of a drive with a coach-and-four through England and Scotland, from Brighton to Inverness. Though printed in a limited edition only, for private circulation in his immediate circle of friends, these two books met with such a reception that new editions were soon demanded, and in 1883 "Our Coaching Trip" was published by Charles Scribners' Sons in an enlarged form, under the now famous title of "An American Four-in-Hand in Britain," and was followed, in 1884, by a similarly enlarged edition of "Round the World."

Two years later Mr. Carnegie published his best known work, "Triumphant Democracy; or, Fifty Years' March of the Republic." The title of the book indicates its scope. It gives a graphic account of the United States and of its people, and of its phenomenal progress in every branch of activity, and draws a comparison between its advancement and that of the older countries during the same period, greatly to the advantage of the country of his adoption. The book won well-deserved success both in America and in Europe, where it was translated into a number of foreign languages, and rapidly ran through several editions, the last one of which, enlarged and brought down to date, was published in 1893.

Mr. Carnegie is a thorough democrat, with an undying faith in the political system of the United States, of which he is a citizen through the naturalisation of his father in 1853, when the son was a minor. But his love for his adopted home and her institutions has not dimmed his affection for the land of his birth, which he visits annually and in whose political future he takes the greatest interest.

A friend of Mr. Gladstone, and in strong sympathy with the radical party in Britain, he has always done what he could to further that party's interests. A few years ago, in connection with Mr. Samuel Storey, M. P. for Sunderland, he formed a syndicate to establish radical newspapers in different parts of Great Britain, and at one time had an interest in eighteen newspapers,—seven dailies and eleven weeklies. As a business venture the enterprise was fairly successful, but as the political results were not altogether satisfactory, Mr. Carnegie disposed of his interests in the enterprise.

Besides his books, Mr. Carnegie has published also many pamphlets and review articles on political and kindred subjects.

Of these articles, the "Gospel of Wealth," published in the *North American Review*, in 1889, and which formed the main theme of an article by Mr. Gladstone in the *Nineteenth Century Review* for November, 1890, presents in clear and forcible language Mr. Carnegie's sentiments in regard to the rich man's duty to his fellow man. To quote his own words,—"The man who dies rich, dies disgraced. That is the Gospel I preach, that is the Gospel I practice, and that is the Gospel I intend to practice during what remains of my life."

That Mr. Carnegie has lived up in the past and is still living up to this radical declaration of independence from the practice of so many men who have amassed fortunes before him, will be

best shown by a brief enumeration of some of his almost unexampled philanthropies, which have given him a world-wide reputation as one of the benefactors of his race. His largest gift has been to the city of Pittsburgh, the scene of his early trials and his later triumphs. There he has built, at a cost of more than a million dollars, a magnificent library, museum, concert hall, and picture gallery, all under one roof, and endowed it with a fund of another million, the interest of which ($50,000 per annum) is to be devoted to the purchase of the best works of American art. He is now building other branch libraries and halls in and around Pittsburgh, having promised to expend, in all, five millions of dollars to give that city the most complete system of libraries, combined with art galleries and halls for the people.

While thus endowing the city where his fortune was made, he has not forgotten other places endeared to him by associations or by interest. To the Allegheny Free Library he has given $375,000; to the Braddock Free Library, $250,000; to the Johnstown Free Library, $50,000; and to the Fairfield (Iowa) Free Library, $40,000. To his native land he has been scarcely less generous. To the Edinburgh Free Library he has given $250,000, and to his native town of Dunfermline, $90,000. Other free libraries in Scotland which he has aided are those at Aberdeen, Peterhead, Inverness, Ayr, Elgin, Wick, and Kirkwall, and he has contributed to the establishment of many public halls and reading rooms at Newburgh, Aberdour, and other places.

Mr. Carnegie has told somewhere in one of his public speeches,—for he is an orator as well as a writer,—how his attention was first turned to the establishment of free libraries. When he began his career as a working boy in Allegheny, a certain Colonel Anderson in that city announced that he would be in his library every Saturday ready to lend books to working boys and men.

"He had only about four hundred volumes, but I doubt if ever so few books were put to better use. Only he who has longed, as I did, for Saturday to come that the spring of knowledge should be opened anew to him, can understand what Colonel Anderson did for me and others of the boys of Allegheny, several of whom have risen to eminence. Is it any wonder that I resolved that if surplus wealth ever came to me, I should use it in imitating my benefactor?"

Mr. Carnegie's philanthropic generosity, which is by no means wholly represented in his munificent gifts for the establishment of free libraries, has won for him the respect and esteem of thinking men the world over, and has brought him other rewards, of which he is very proud, among them the freedom of seven cities of his native land, including the capital. But greater than all to him must be the consciousness that he has been enabled, through his own exertions, to do something for the service of his fellow man, something that tends to elevate the race. I cannot conclude better than by quoting his own words in an address before the Nineteenth Century Club, of New York:—

"What a man owns is already subordinate in America to what he knows; but in the final aristocracy the question will not be either of these, but what has he done for his fellows? Where has he shown generosity and self-abnegation? When has he been a father to the fatherless? And the cause of the poor,—where has he searched that out? How he has worshipped God will not be asked in that day, but how he has served man."

But notwithstanding this strong expression of his sentiments, Mr. Carnegie does not believe in indiscriminate charity, which he thinks is too often misplaced. His view is that "of every thousand dollars given, nine hundred and fifty had better have been thrown into the sea," and that "to help only those who help themselves should be the aim of every giver." He has often expressed his reluctance to accept the title of philanthropist, which, he holds, usually "means a man who has good impulses, but is destitute of good sense."

ROLLER BEARINGS FOR MACHINERY.

By H. A. Richmond.

THE circular form, as a friction saver, has been familiar through all ages in the common cart wheel; and the metal or wooden roll is in use the world over to-day wherever there is heavy merchandise to move. Indeed, the shop foreman would be at a loss to get his machines into place without its assistance. For rather more than sixty years inventors have endeavoured to embody this principle in a form which should be practicable for all classes of journals, and in spite of repeated failures and the steady improvement in friction journals through the use of better babbitt metal, ring oilers, prepared graphite, etc., this endeavour has persisted and grown until to-day it may be stated, without fear of contradiction, that the roller bearing, as applied to machinery, has come to stay.

The reason for this is not far to seek. The service demanded of the journals of many modern machines, by reason of heavy pressures and the high speeds now common, is such that heating, loss of power and rapid wear are the inevitable results. Machines that otherwise might continue in use for years without the slightest outlay for repairs, must be periodically shut down to have their journals adjusted, rebabbitted, or replaced. Frequently a machine must be idle a considerable part of each day to allow the bearings to cool down.

But it is not only in these acute cases that the amount of energy actually wasted through journal friction is astonishingly large. The uninformed man who enters a shop and sees a long line of shafting rapidly and noiselessly revolving, is inclined to think, "How easily it turns!" He cannot realise how much steam must be made and used simply to keep the line going. The writer has lately investigated a modern, well-built factory where the amount of power necessary to turn the shafting alone amounts to exactly 50 per cent. of the total horsepower needed when the full complement of machines is in use. Nor is this percentage of loss exceptionally high, even where the shafts are apparently running smoothly and in good alignment. There are few managers to whom it would not be an object of interest to save a quarter or a third of their coal bills.

The undeniable fact is that an enormous volume of energy is daily being wasted in journal friction, in causing metal surfaces to laboriously rub past each other, and so wear themselves out. And it is the appreciation of this fact, the knowledge that a real need for something better existed, that has induced the persistent effort to make a roller bearing which shall be cheap enough, durable enough, and simple enough to permit of its general application to machine journals. The designer and the engineer are constantly on the alert to increase the efficiency of the steam engine a paltry 2 or 3 per cent. It is, therefore, not strange that a problem whose solution promised a dozen times this saving in power should have proved an attractive one.

An instructive experiment for those who are not familiar with the advantages of rolling friction over sliding friction may be made as follows:—Take any flat surface, as a book, and place upon it some small flat bottomed article, say a paper weight. Now slowly raise one end of the book until the weight starts to slide down, and note the angle at which you are holding the book when the weight begins to move. Then re-

peat the experiment, using a cylindrical piece, say a spool, instead of the paper weight. In the first case an angle of perhaps 20 degrees will be found necessary, while in the second, 1 or 2 degrees will be enough.

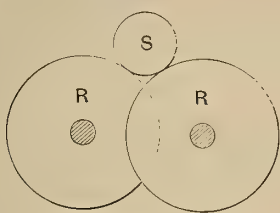


FIG. 1.

All roller bearings may be divided into two classes:—

First—Those in which the axes of the rollers remain fixed.

Second—Those in which the axes of the rollers travel about the shaft.

The first class is small, but includes one familiar example, that of the common "grindstone bearing," shown in Fig. 1. In this bearing the shaft *S* rests on two overlapping rollers *R R*, which revolve on fixed axes, as shown. This device, patented in Great Britain in 1854, by a Frenchman named Pomme, was, for a time, regarded with high favour, but soon developed defects by

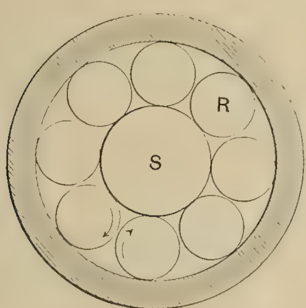


FIG. 2.

reason of the unavoidable wear on the axes of the rollers It is, in fact, rather a speed reducer than a roller bearing, and has met with very limited application outside the appliance which gave it its name.

It is to the second class that the great majority of roller bearings belong. Obviously, the simplest bearing of this type consists of a series of plain rolls *R*, arranged around the shaft *S*, and travelling between the latter and the housing or box. This bearing was formerly made with soft steel rolls of more or less accuracy as regards size, these running in a cast iron box. It worked well for a very short time. Then the box and rolls, which were in contact with one another, would become worn, so as to allow the latter to get out of alignment with the shaft, and rapid ruin of both box and rolls resulted.

To avoid these difficulties the rigid frame or cage was invented. It is designed to serve a double purpose. First, to guide the rolls in lines parallel to the axis of the shaft; and, second, to separate the rolls so as to prevent frictional contact between their adjacent surfaces.

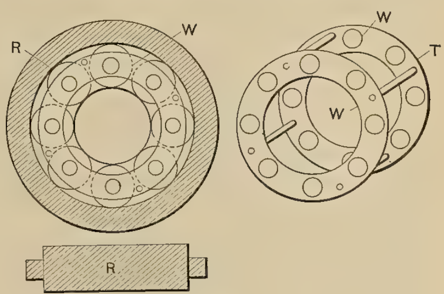


FIG. 3.

Referring to Fig. 2, it is apparent that the adjacent surfaces of any two rolls are moving in opposite directions and are thereby developing friction at their points of contact. During the last forty years this cage has appeared in a bewildering variety of forms, most of which display a misconception on the part of the inventor of the service demanded of it.

A common form is shown in Fig. 3, where the cage is composed of two washers *W*, held together by tie rods *T*. The rollers, *R*, have small journals at either end which revolve in holes in the washers.

In another form the rolls are made hollow and the tie rods pass through

them, being made fast either to one washer in the middle, or to a washer at either end, as shown in Figs. 4 and 5.

One or two other methods of separat-

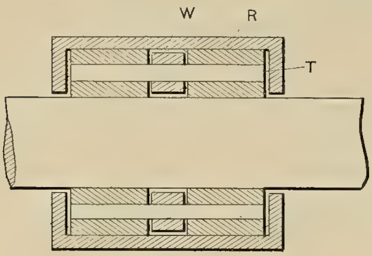


FIG. 4.

ing the rolls will be of interest as showing the ingenuity spent upon this device. In Fig. 6 is shown an arrangement patented in 1872, where a series of overlapping rings, *O*, confine the ends of the rolls *R*, the shaft and box being cut away to make room for the rings. An examination of this arrangement will show that each pair of adjacent surfaces move in the same direction, thus avoiding the friction and wear ordinarily developed at this point. The arrangement is further interesting as suggestive of the Meneely tubular bearing, which will be referred to later. Fig. 7 shows Harris's use of gears to guide the rollers, and Fig. 8 illustrates Brus-

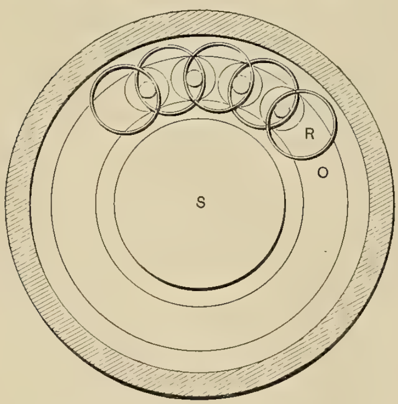


FIG. 6.

sant's patent in which use is made of links which pass around the ends of the rollers to keep them in place.

Without stopping to discuss the mistakes of design or construction by reason of which these bearings failed to accomplish their purpose, we may pass on to a consideration of the types which

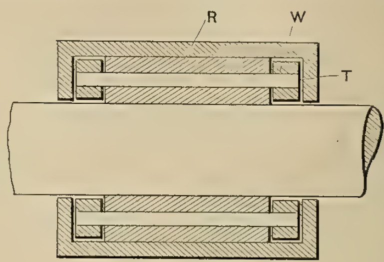


FIG. 5.

are being offered to the public to-day and the several uses to which they have been put. It is a somewhat singular

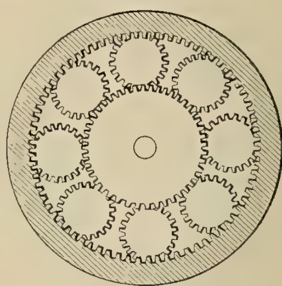


FIG. 7.

fact that these have all been introduced within the past five years, and it is perhaps equally remarkable, in view of the unbroken record of past failures, that they have all met with so large a measure of success,—a success that is plainly on the increase. This, it may be stated, is due as much to the development of mechanical and metallurgical processes employed in their manufacture, as to novelty or ingenuity of design.

It is safe to say that fifteen years ago it would have been impossible, even with present designs worked out, to manufacture in any way then known most of the well-nigh perfect devices now in use, much less at a cost which would place them within the reach of machinery builders. Indeed, this matter of first cost has been a serious obstacle to their introduction in the past. In no small degree is their present wide appli

cation due to the fact that they are being produced and sold to-day at a price which would have been pronounced wholly visionary a few years ago.

Certainly first in ingenuity of design,

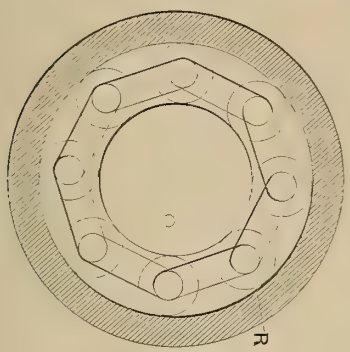


FIG. 8.

though probably not destined for such general use as some others, stands the Meneely tubular bearing, the result of elaborate experiments conducted by Mr. C. D. Meneely, of Troy, N. Y. Two views of this are shown in Figs. 9 and 10. Fig. 9 shows the bearing with the side of the box removed, exposing the three sets of tubular rollers. Fig.

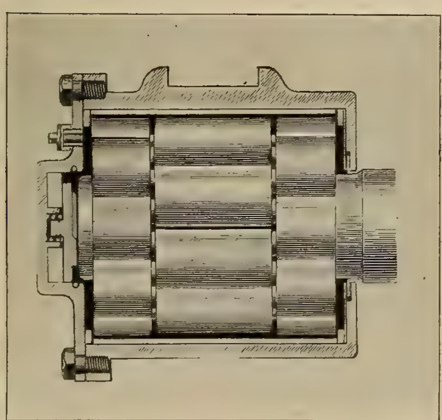


FIG. 9.

10 is a section showing how the short rolls at the ends overlap the long ones in the middle. All the rolls are made hollow, and through the intersecting concavities formed by their overlapping, are passed steel rods extending from end to end. These rods serve to keep in alignment the hollow rolls, with whose interior surface they are in rolling contact.

The action is precisely the same as that of the rings on the ends of the rolls shown in Fig. 6. It is apparent, therefore, that there is no sliding or rubbing friction in this mechanism, except upon the ends of the rollers. In practice a steel sleeve is fitted into the cast iron box to insure greater durability.

This bearing was designed especially for use on the journals of railroad cars where the service is of the severest kind, owing to the constantly repeated shocks to which the wheels are subject, combined with a high speed of revolution. So far as the writer knows, it has not

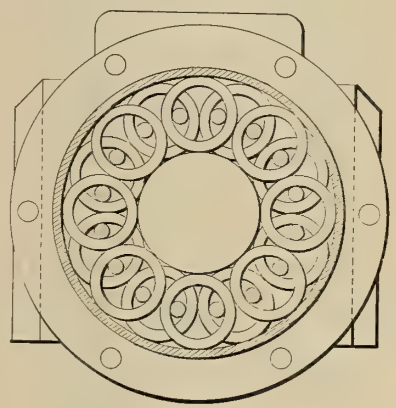


FIG. 10.

yet been applied in any other department of mechanics, but recorded tests prove that it is well suited to the purpose for which it was devised. The following table, taken from an interesting pamphlet published by Mr. Meneely, is a forcible answer to the objection of higher first cost which is frequently urged against roller bearings:—

Economy actually effected in fuel lubrication and wear in operating a four-car accommodation passenger train four years (mileage nearly 800,000 miles).

COST OF OPERATION WITH BRASSES.

	$	£	s.
4,500 tons of anthracite coal (45 lbs. to the mile), at $3.50 per ton.....	15,750	3,150	
Lubrication, $30 per car per year.	480	96	
Renewals of bearings, four times, $12 per car, including extra waste and oil..................	192	38	8
	16,422	3,284	8

COST OF OPERATION WITH TUBULAR BEARINGS.

	$	£	s.
3,375 tons of coal (25 per cent. saving)	11,812.50	2,362	10
Lubrication, $6 per car per year	96.00	19	4
	11,908.50	2,381	14
Saving in operating expenses	4,513.50	902	14

DIFFERENCE IN COST OF EQUIPMENT.

	$	£	s.	d.
32 tubular bearings, at $50 each	1,600	320		
Less cost of 32 oil boxes and brasses, at $5 each	160	32		
	1,440	288		
Net train saving	3,073.50	614	14	
Net train saving per year	768.37	153	13	6
Net saving per car	768.37	153	13	6
Net saving per car per year	192.09	38	8	4½

It will be noted from the above that though these roller bearings have been in use a period of four years, the cost for repairs and renewals has been absolutely nothing, whereas ordinary brasses must be renewed annually. It is further stated by Mr. Meneely that on a level track a push of 252 pounds will start a train of four passenger coaches, weighing 204,000 pounds, when mounted on roller bearings. When on plain bearings, 3276 pounds are needed. Thus the co-efficient of starting friction is reduced from .016 to .0012, or about 92 per cent.

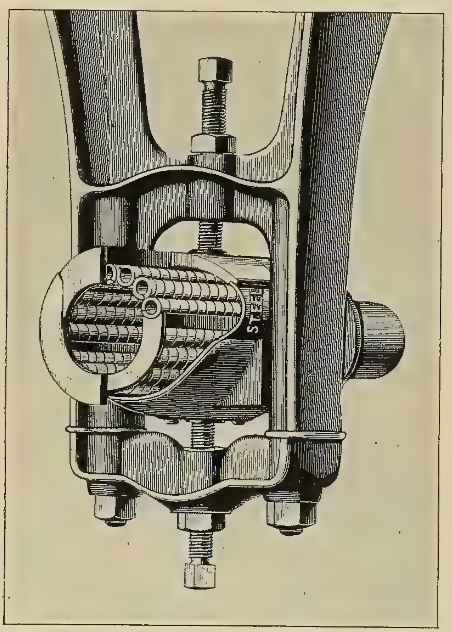


FIG. 11.

These results are very nearly duplicated by those obtained in a series of tests lately made on horse and electric tramcars at Morecambe, India. In addition to starting tests there were made tests from an incline, allowing cars to run to a standstill on the level at the bottom of the incline. It was found that the car on roller bearings ran about six times as far as the one on brasses. Power tests on electrically driven cars showed a saving of over 30 per cent., but this included a run over elevations, where the power necessary to lift the car against gravity is the same in either case. It may be fairly stated from other tests which have come under the writer's knowledge, that the actual saving in moving friction (as distinguished from friction of starting) is more than 50 per cent. over plain car journals.

The principal objections to the Meneely bearing, in considering its practicability for ordinary machine journals, are:—

First—It is cumbersome, since the tubular rollers must be of large diameter to sufficientlv overlap one another. In a large proportion of the machines now in use it is not possible to make room for so bulky a device.

Second—It cannot be split. For line shafting and many other purposes this is a most serious objection.

Third—It is costly compared with other roller bearings now on the market.

Reference has already been made to the loss of power in causing lines of shafting to revolve. Fig. 11 shows a roller bearing made by the Hyatt Roller Bearing Company, of Newark, N. J., which has been especially designed to mitigate this evil. As in the Meneely bearing the rollers are tubular, but are here ingeniously wound up into spiral form from strips of sheet steel. This construction endows them with great elasticity, if not with absolute perfection of form or uniformity of size. A yoke is used, extending half around the journal, and from end to end, to assist in preserving the parallelism of the rollers. The outer box consists of a sheet steel lining supported by castings which receive the points of the adjusting screws.

These bearings have been extensively

applied to mill shafting and with an acknowledged saving of power. Exactly what this saving is, must depend upon local conditions. The following results are taken from a report of tests made at the works of the W. L. Gilbert Clock Company in Winsted, Conn., where 600 feet of shafting are running on 104 of these bearings:—

	H. P.
Power developed by water wheel	40
Power absorbed by shafting alone, running on babbitted bearings	25.02
Power absorbed by shafting alone, running on roller bearings	18
Power saved by roller bearings	7.02

In other words, the saving in this case amounted to 47 per cent. of the power previously available, and 17.5 per cent. of all the power developed. It is instructive to note that the power absorbed by the shafting alone, running on babbitt boxes, was 62.5 per cent., or considerably more than half of all the power delivered by the water wheel.

Many of these bearings have been in use for two or three years and have yet failed to show serious wear. Other applications than to line shafting have been made with this type, some of which will be referred to later.

The obvious disadvantages of the design are:—

First—The rollers are in surface contact with one another under pressure, and thus develop more friction than if properly separated. This is apparent when it is considered that the adjacent surfaces of the rollers are moving in opposite directions.

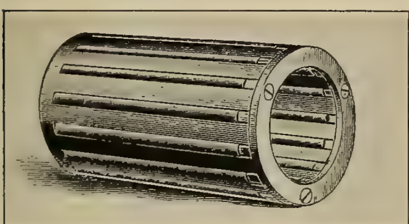


FIG. 12.

Second—The rollers must be handled separately in setting up the bearings, thus making a multiplicity of parts to care for.

It is not uncommon to hear it stated that the use of a rigid frame or cage in a roller bearing defeats the very purpose of an anti-friction device, on the ground that friction is developed between the rolls and the cage. Such critics forget that the cage is not under pressure, but is merely carried around by the rolls. Since friction is proportional to pressure the amount in this case must be exceedingly slight, especially if, as is common, the cage is made of brass.

About three years ago the Mossberg & Granville Mfg. Co., of Providence, R. I., began applying a roller bearing of the cage type (Fig. 12) to the metal rolling mills which the company was then manufacturing. In this bearing solid hardened tool steel rolls are used and hardened bearing surfaces. Both surfaces and rolls are ground after hardening. It is this thorough and careful workmanship which accounts for the successful results obtained from the use of rolls under the severe strains which come upon the journal of a metal rolling mill.

A large number of users of these rolling mills have testified to the remarkable saving of power from the application of roller bearings. More than two years ago the company applied a set of rolls to an 8×5 inch mill at the factory of the Brown & Sharpe Manufacturing Company at Providence, R. I. The journals measure 3½ inches diameter and are 4 inches long. The superintendent told the writer that before using roller bearings the mill had been driven at a speed of 15 feet per minute by a 6-inch belt with a 4-inch rider. The belts were stuffed and run very tightly. After the new bearings had been applied, a one-inch belt was sufficient to drive the mill as fast as the two belts did previously. A 2-inch belt is now used, and the speed has been increased to 32 feet per minute. The mill is now run ten hours a day without heating, though previously it had to be idle two or three hours a day to cool the journals. No perceptible wear has yet appeared, and the foreman stated that finer work was now possible than with bronze boxes, possibly owing to the higher speed of the rolls.

The application of roller bearings to these machines has demonstrated a saving of from 50 to 70 per cent. in the power necessary to drive them.

The Mossberg & Granville Mfg. Co. have also applied their bearings to the journals of an electric car belonging to the Interstate Consolidated Street Railway Company, of Rhode Island. After a run of 21,000 miles there was no perceptible wear and it was admitted by those in authority that the saving in power amounted to 50 per cent. over ordinary brasses.

The same company has lately devised a roller bearing to relieve the friction of thrust, and reported tests indicate a co-efficient of friction of only 0.0025, compared with a co-efficient of 0.05 obtained with a plain bearing working under the same conditions. The pressure was 104.5 pounds per square inch. It is evident that the difference in favour of the rolls is 95 per cent., or nearly all of the friction of plain collars.

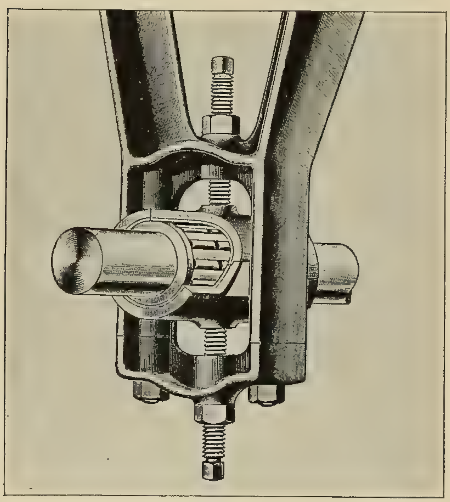


FIG. 13.

Unfortunately the rollers must be true cones in a thrust bearing, and the collars must be ground into exactly supplementary cones to secure the best results. These conditions make this bearing a costly one to manufacture, and in view of the fact that ball thrust bearings are to-day sustaining loads as high as 100,000 pounds, the field for rollers in this class of work would appear to be limited.

Mechanics realise that the variety of uses to which a durable roller bearing for journals may be put is unlimited, provided these can be produced at a reasonable price. It was the appreciation of this fact which induced the Ball Bearing Company, of Boston, Mass., to place upon the market a bearing of the cage type which should be within the reach of all machine builders. In this bearing (Fig. 13) a series of short rolls are used in each flute, instead of one long one. The former are far easier to make, since they will not spring in the hardening, as a long roll invariably will. This avoids much grinding. Furthermore, the short rolls will better adapt themselves to small inequalities in the bearing surfaces. The design of the cage is such as to insure great accuracy of workmanship, combined with ease of construction.

This bearing is manufactured for general machine purposes and has been successfully applied to a great variety of machines, such as motor vehicles, fans and blowers, gas and steam engines, grist mills, paper and textile machinery, windmills, electric dynamos and motors and many others. The percentage of saving of motive power in these machines varies according to the proportion which the energy used up in bearings of the ordinary type bears to the total power consumed by the machine. For instance, in Fourdrinier paper machines relatively little work is done by the machine, most of the power being used up in overcoming the friction of the cylinder journals in their boxes. If this forms 75 per cent. of the total power, and 80 per cent. of it can be saved, then will the total power needed to drive the machine be reduced $0.75 \times 0.80 = 60$ per cent. On the other hand, if the friction loss is small, only a relatively small power saving can be made.

It must not be forgotten, however, that reduction of power is not the only gain to be derived from the use of rolls. A properly constructed roller bearing,

suited to the work it has to do, will outlast many sets of brasses. A large steel works reports that their roller bearings are still doing good service after four months' use where bronze boxes had to be renewed every three weeks. Reference has already been made to the relative frequency of renewals of bronze and roller bearings on car journals, and other cases of a like character might be cited to indicate the superior durability of rollers.

This matter of durability is, indeed, the pith of the whole roller bearing question. Nearly all the roller bearings that were ever tried probably gave surprisingly good results for a short time, — and then failed, because they were not adapted for the particular work they had to do. The workman who endeavours to cut all kinds of metal with one form of lathe tool soon finds his mistake; but he does not condemn all lathe tools on this account. Nor should the mechanic condemn roller bearings because one that was designed for heavy, slow work, fails at high speed.

It is entirely practical in a slow moving truck to allow the rolls to travel on relatively soft surfaces, and good results have been obtained in this class of work when these were made of cast iron; whereas the writer has known cast iron to be grooved one thirty-second of an inch in half a day's run at 1200 revolutions a minute and with uneven pressures. All the companies manufacturing roller bearings now furnish either sheet steel or hardened steel sleeves with the rolls, and to this precaution much of their success is attributable.

Indeed, were it not for the additional cost it would be wise never to use rolls for any purpose without provision of this sort. It is, in the writer's opinion, due to this employment of better bearing surfaces, combined with improved machine-tool methods, that the final triumph of this device has been achieved. It is a product of the times, conceived in a long existing want, and brought to life by the wonderful development of mechanical processes which recent years have witnessed. For the modern roller bearing is a mechanism of the greatest nicety of construction; lacking which, it would cease to be an article of value and become merely another failure in the long line that preceded it.

Nothing has been said regarding maximum speeds which are practicable with roller bearings, and after what has been written very little is necessary. For, since heating is the result of friction, it is apparent that by whatever amount we reduce the latter, by just so much do we lessen the tendency to heat and all experiments confirm this reasoning. In one series it was found that a 2½-inch babbitt journal, under a pressure of 200 pounds per square inch of projected area heated at 800 revolutions per minute, with oil supplied at the rate of twenty drops a minute. The same size journal on roller bearings under the same load failed to warm up at 2600 revolutions. Roller bearings applied to the 1½-inch journals of a "fleshing" machine have been run continuously at speeds of 2000 revolutions per minute without signs of heating. In this machine the pressure is a little less than 1000 pounds per bearing.

One firm reports a test where a 14-inch pulley, weighing 130 pounds, and mounted on rollers, was speeded up to 10,000 revolutions per minute, and this was repeated a number of times without damage to the bearings. An interesting fact connected with this test is that the pulley continued to run one hour and thirty-three minutes after the source of power had been suddenly disconnected.

In view of these and other facts which might be quoted, it is reasonable to believe that the modern roller bearing is capable of far higher speeds than ordinary journals, without undue wear or danger of heating, and without the necessity of those elaborate devices for supplying a continuous stream of oil which present practice frequently demands. For the roller bearing requires but little lubrication under severe conditions of service, and none at all when the speed is very slow, as in trucks and hand cars.

With so much to commend them it

may be asked, "Why are not roller bearings in more general use on machinery?" In reply it must be stated that their use is rapidly and steadily increasing. The mechanical world has never been so alive to their advantages as it is to-day, and new applications are constantly being discovered. It is a matter of regret that lack of space forbids a detailed description of more of these, for even now the variety of uses to which they have been put and the benefits accruing from their application are not generally understood.

Again, the question of price operates to retard their wider adoption. It is comparatively easy to introduce an improved device at the same price as that at which its competitor is sold; but it is not so easy to convince a buyer that the improvement warrants the payment of a higher price. Above all, however, the roller bearing has to overcome the strong prejudice which a long, and hitherto uninterrupted, record of failures has naturally raised against it. Old mechanics say:—

"Yes, we tried roller bearings twenty-five years ago. They didn't work."

To them this may be sufficient evidence to convict. Possibly they forget, for the moment, that the world, especially the mechanical world, has taken enormous strides forward since then; that twenty years ago it was predicted that the telephone would never be more than a toy; that few mechanical devices are perfected in a day; and that the problem of successful mechanical flight, though it has at least as many failures charged against it as have roller bearings, is still able to command the efforts of some of the best engineers.

One by one the mechanic's Gordian knots are being cut. And in the record of these, the production of a practicable roller bearing will stand as not the least important improvement in modern machinery.

CLIFF RAILWAYS.

By G. Croydon Marks, A. M. Inst. C. E.

THE development of sea coast towns in England as health resorts for the accommodation of visitors has led to the necessity of placing the cliffs and higher level ground in direct communication with the sea shore or lower level ground by means of inclined tramways or, as they are more generally termed, cliff railways.

The distance, as a rule, is not great, but the visitor is not usually inclined to make an ascent of a tortuous path more often than is necessary in order to have the benefit of the sea shore charms and attractions. The railway has, therefore, to be rapid in its speed, simple in action, and safe to the degree of sentimental security, in order that invalids, as well as the ordinary visitors, desiring to save wind and limb may have confidence in it.

The writer was required to comply with these conditions when acting as engineer for the Lynton and Lynmouth Cliff Railway in England in 1887. This line, which has a length of about 900 feet, with a vertical rise of about 490 feet, unites the two places named by means of two lines of rails, laid upon sleepers which are bolted down to the solid rock, or to blocks of concrete where the nature of the bed exposed for the track did not admit of a good solid hold being obtained for the fang bolts. The rails are laid to a gauge of 3 feet 8 inches, and the larch sleepers are placed

THE LYNTON AND LYNMOUTH CLIFF RAILWAY.

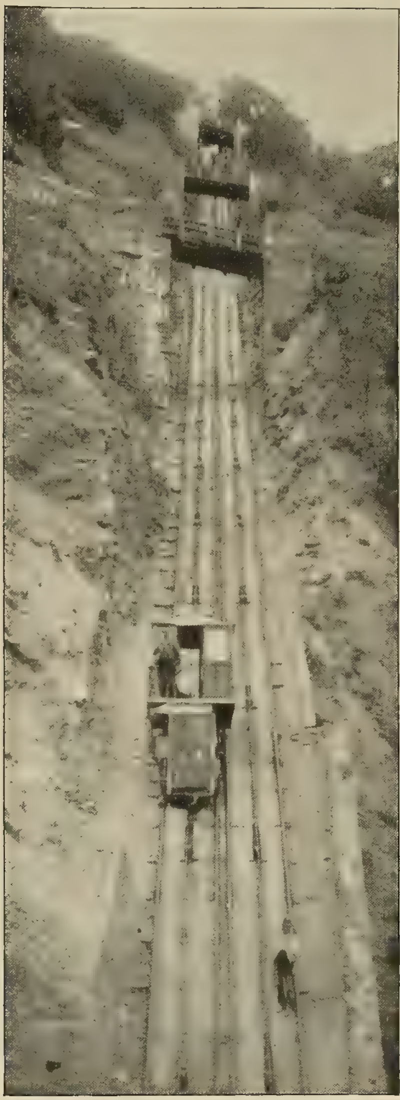
about 6 feet pitch for the entire length of the rock track. The cliff was cut away to a depth sufficient for enabling the cars to pass under the foot paths and roadways, shown on the illustrations, and the rails were laid with a widened loop at the centre where the two cars pass each other.

The motive power employed is water, acting as a gravity balance when in the upper car to draw up the loaded bottom car. Each car is connected to the other by means of two steel wire cables, each one of these being of ample strength, with a margin of safety of ten to one, for carrying the maximum load. The cars are formed with a horizontally level platform upon which is attached the passenger carriage, which is capable of being readily removed when goods or ordinary carts are to be raised instead of passengers. The system of working provides generally that goods shall be carried only during the early morning hours when little passenger traffic is to be expected.

Beneath the platform or level floor of the under-frame are arranged one or more tanks for carrying the water ballast, provided with inlet and outlet valves so that when the descending water-loaded car reaches the lower station the water can be discharged into the drains, ready for the up journey when only a load of goods or passengers will have to be carried. In the event of a heavy down load of goods or passengers being obtained, the conductor at the upper station telephones to the conductor at the lower station, and the whole of the ballast water is not then discharged should a light up load only be ready when the top car is signalled as loaded and ready for starting.

The water is obtained from the River Lyn running through Lynton, and the feed pipes are taken from the river to fill a storage reservoir at the upper station, and from this reservoir the car conductors fill the cars by manipulating a valve adjacent to the upper landing platforms. The amount of water allowed to enter the car tanks is determined by the number of passengers or load signalled up from the bottom station as being the freight for the next journey.

To balance the two ropes, a tail rope was originally placed from the back of one car to the back of the other after passing round a bottom track pulley; but the inconvenience of such a rope



LYNTON AND LYNMOUTH CLIFF RAILWAY.

and the necessity of adjusting it to produce a perfect balance has led the writer to consider it not worth providing upon other cliff railways constructed by him subsequently.

It is not always possible to find a source of water supply running to waste at the upper level for use as ballasting water, and arrangements must, therefore, be made for economically using ordinary town main supply. To draw continually from the water company's main would be prohibitive in price, seeing that ballast alone is required and not pressure as in the ordinary hydraulic lift cylinders. The writer has therefore constructed other such railways, when water was not freely obtainable, with storage reservoirs provided both at the upper and lower stations, and at the lower station pumps have been arranged for raising the water back to the upper reservoir when the water in the lower reservoir has reached a certain level.

The Clifton Rocks railway, the Bridgnorth Castle Hill railway, and the Aberystwyth Cliff railway, designed and constructed by the writer, are on this principle. The pumps at Clifton and Bridgnorth are driven by gas engines, and at Aberystwyth by steam. The engine room in each case is placed over the lower reservoir, the arrangement of the room being such as not to interfere with the convenience of the passengers in the waiting room. The amount of water used is, in every case, proportioned to suit the load to be carried, and when rushes of down traffic occur during a pause or diminution in the up traffic, no water at all is required, the passengers themselves supplying the needful ballast to bring up the lower car.

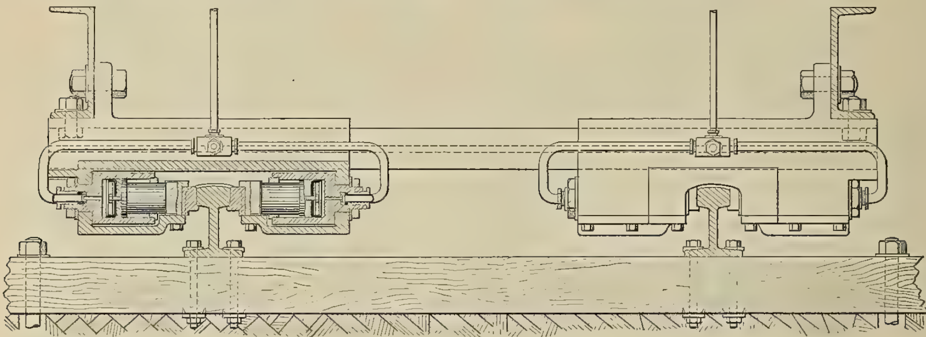
The safety arrangements are designed to meet the fears of the nervous, the writer considering it desirable to leave nothing to any single safeguard, or nothing for any separate piece of mechanism to do to arrest the motion of the car. In the first place, the attendant who is required to travel upon the foot plate of the car, away from the passengers, has the opposite duty to perform to that nominally assigned him, viz., he is required to prevent the car from stopping, not so much to stop it by what he does. He manipulates a windlass which raises a weight so that the water in an accumulator shall not be subjected to pressure from this weight, and by so doing

THE BRIDGNORTH CLIFF RAILWAY.

the hydraulic rail gripping brakes are not able to press against the rails with sufficient pressure to hold the car; when, however, the suspended weight is released, the water from the accumulator passes through pipes to the rail-gripping cylinders, as shown in the diagram on the opposite page, causing the rams to force brake shoes against the rail head with a gripping pressure sufficient to hold the car with its load in any position. This pressure can be increased by the attendant, when so desired, to arrest any momentum.

The water supplying the accumulator is drawn from a separate cistern placed in the main tanks of the car under-frame, the necessary pressure to force it into the accumulator cylinder being obtained by pumps worked from eccentrics mounted on the rail wheel axle. These pressure pumps are in duplicate and are connected to the brake cylinders by independent pipes, so that one pump supplies one pair of brakes, and the other, the opposite pair. A pressure of 250 pounds per square inch has been found sufficient to hold the cars, but the pumps are designed to work up to 1000 pounds. Gauges from each pump main pipe indicate to the attendant the pressure he has available.

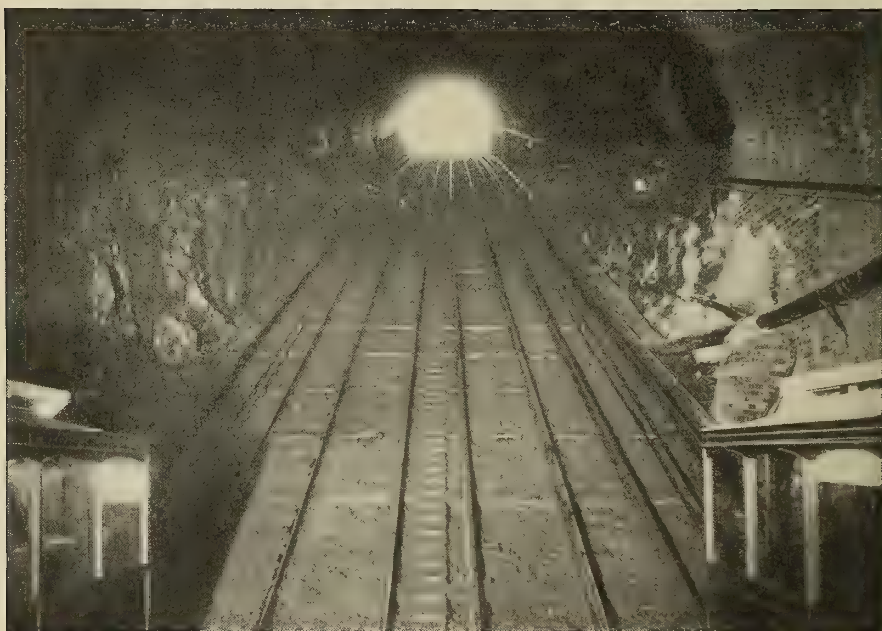
Rope safety brakes are arranged to provide for any stretching of the ropes, and as a rope will always stretch before it breaks, the anchorage to the cars is made such that should either rope give way, the safety wedges would be drawn into the wedge boxes and the car locked to the rails.



THE RAIL-GRIPPING DEVICE.

To provide for any emergency, a hand or foot lever is arranged as an emergency brake which, when moved, throws in the rail wedges quite independently of the action of the rope anchorage arrangements. A governor or speed brake is mounted on the under-frame to prevent any undue speed.

The Clifton Rocks railway is constructed on the form of an inclined tunnel through the St. Vincents rocks near the Suspension Bridge, Clifton, Bristol, and is interesting in that it has four distinct lines for dealing with the heavy traffic upon holidays in the district, the demands being such that on many oc-



IN THE TUNNEL OF THE CLIFTON ROCKS RAILWAY, BRISTOL.

casions 1500 passengers per hour have travelled in the cars. The tunnel is brick-lined throughout, the timber shorings which were employed for keeping up the faulty limestone rock being built in. The Bridgnorth track was cut through solid red sandstone and the Aberystwyth through a limestone, shale and slaty formation. The cars at Aberstwyth are arranged in stepped seats, instead of with a level platform, and carry fifty passengers per journey.

In addition to the safety appliances provided upon each car, the writer has placed a specially designed strap or band brake around the top rope wheel for use by the water supply attendant as a further precautionary measure for checking the cars when arriving at the platforms. This brake is not absolutely necessary, as hydraulic long-stroke buffers check the motion when nearing the end, but the severe gradient of one in one and one-half, which exists on one of the lines, induces a desire for absolute certainty in dealing with such exceptional risks, and the millions of passengers who have been carried without accident upon the system of construction warrants the suggestion that every possible precaution and provision has been adopted to safeguard the passengers travelling upon such cliff railways.

Current Topics.

THERE is a growing tendency in some large power plants to introduce condensers of the so-called "central" type, one large condensing apparatus being used to maintain a vacuum into which all the various engines, pumps, and compressors discharge their exhaust steam. This central condenser has its own air and circulating pump, and forms a sort of negative generator at the opposite end of the power chain from the boiler, with a steady "pull," so to speak, upon all the motors in the establishment. This is the extreme development of the separate condenser idea of Watt, and is the logical outcome of the evolution of his original invention. Such condensers are especially coming into use in Germany, being installed at Krupp's, Mannesmann's, and other large establishments, and their construction has already developed into a large and important business. Apart from the general economy of the use of a condenser there is the additional advantage that a great number of small engines, pumps, and the like, which, in ordinary plants, would

be puffing and barking away into the atmosphere, are operated condensing as a matter of course when there is a general vacuum tank at hand. Such central condensers might be profitably installed wherever there is sufficient water available.

WAR is always a horrible possibility in the present condition of European politics, but when divested of its personal and political details it cannot but possess a peculiar fascination for the engineer, especially since engineering has so largely entered into all the methods of modern warfare. Since the last great war, the machinery of warfare has been almost entirely recreated and, indeed, many devices have been invented, constructed and become obsolete without ever having had a chance to show what they were worth in actual combat. Should the great powers become involved in warfare, however, there is no doubt that numerous mechanical devices, till the present kept secret, will appear in various lines of fighting machinery, and it is not impossible that, as in the days of the *Monitor*, armaments and equipments upon which millions have been spent, will find themselves relegated to the curiosity shop over night.

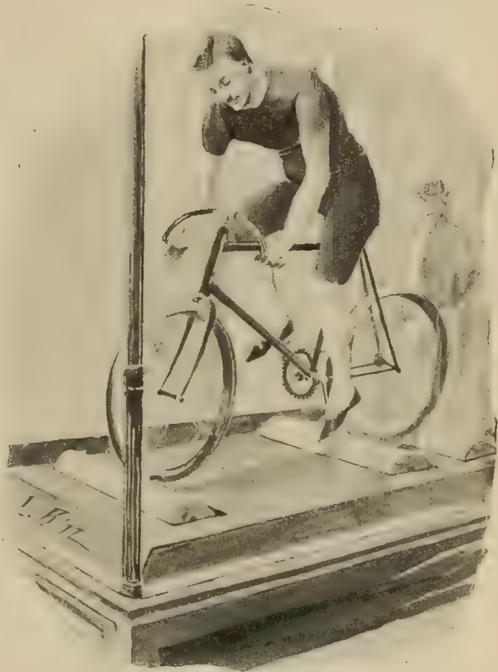
THE restless ingenuity of the inventor is almost as much of a bane to the leaders of commercial warfare as to the war lords of militarism. It has been said, and doubtless with truth, that the managers of the great commercial combinations consider the possibilities of superseding inventions as the greatest element of risk in their calculations. From this point of attack industrial combinations are almost helpless, for no degree of business skill can avail when whole plants are rendered obsolete by the advent of some new device or process which may supplant the entire method of manufacture, if not the product itself. It is this equalising element which may, in obedience to the law of supply and demand, check to a great extent the growth of commercial combinations, intended to control production, prices and business. The very success of a business combination sets inventors to work devising methods, processes and machines to accomplish similar results by other means, and no man knows what a day may bring forth when the tide of invention is turned in any one definite direction. The natural laws of the physical forces must control in the end, and it is to those laws that the development of the commercial side as well as the technical portion of human industry must look for ultimate guidance.

AMERICAN enterprise in the erection of big buildings for business purposes has become known the world over. Twenty-five-story structures have ceased to be startling wonders to inhabitants of the large cities of the United States, and "sky-scrapers" of even more commanding heights are the talk of many prospective builders. For the engineer these piles of stone and metal hold varied and important interests. From the beginning of their foundations his services are indispensable, and, after completion, the maze of machinery which they hold continues to require them, for advice as well as management. Like the modern ocean steamship, the large business building of the present day harbours, deep down, out of sight of all but the operating force, a magazine of power of which the proportions are but vaguely guessed at by the multitude above. Boilers, engines, dynamos and pumps there are in bewildering numbers, supplying heat, light and power to the upper regions through miles of pipe and wire; humming blowers and exhaust fans both supply and abstract air through many-branched ducts for ventilation purposes; and ice and refrigerating machines, too, often must have a place, all helping to make up a machinery equipment of magnificent extent. One measure of this,—perhaps as good a one as can be given,—is the money value of the outfit. In one building, a hotel structure, now go-

ing up in the city of New York, the cost of the steam power, heating and ventilating plant will be in the neighbourhood of \$250,000, or about £50,000, while that of the electric lighting installation will figure up to even more,—\$300,000, or about £60,000.

A COMPARISON of the different methods of doing what is practically the same thing in various parts of the world, is both interesting and amusing to the thoughtful observer. On American ferry boats the import is well known of the "ting-ting" or "jingle-jingle" of the bell by which the man in the wheel house communicates with his fellow mortal in the engine room. On the Thames, however, it would be considered practically impossible to convey information in this manner, and the captains of the small paddle steamers on that stream, stand on the paddle boxes and sing out "ease 'er," "back 'er," etc., apparently to nobody in particular, while these interesting remarks are promptly repeated, in shrill tones, by a small boy into a speaking tube which communicates with the lower regions. On the Seine, in France, this process is simplified, and a large trumpet-shaped mouthpiece flares out in front of the man at the wheel and he yells his commands into this funnel, the other end of which is supposed to reach the engineer. The large steamers on the Rhine, in Germany, are controlled, not by the usual wheel placed in a wheel house forward, but by a very large wheel on a vertical axis, placed right amidships upon an elevated platform or bridge, and several men pass the handles from right to left, or upon occasion trot round in a circle, and it would, doubtless, be considered a serious temptation of Providence, or at least a reflection upon the Fatherland, if any one were to attempt to construct a Rhine steamer with the ordinary form of steering gear.

BICYCLE building and riding have brought in their train a host of inventions, great and small, all more or less directly designed to improve the product of the bicycle factory and to add to the convenience of the rider of a wheel. Of these, bicycle exercising machines are modest, but none the less interesting, specimens. Their object, as may be readily inferred, is to afford riders the means of making regular use of their wheels indoors, in confined spaces where such a thing as a bicycle track, how-

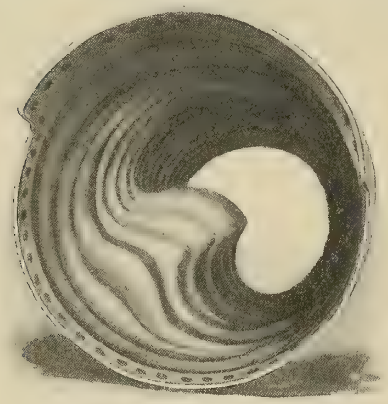


A BICYCLE EXERCISING MACHINE.

ever small, is not to be thought of. One variety of such exercising machine which, in its application seems to be quite new, is shown in the accompanying sketch, drawn from a recent shop window exhibition. This explains itself so well that little need be added to make its operation clear. The apparatus consists simply of a box platform in which three wooden rollers, about 24 inches long, are mounted so as to project somewhat above the platform level. They are spaced so that two of them serve as a support for the back bicycle wheel, while the third acts as a rest for the front

wheel, and their length may be taken to represent the width of a bicycle path. A bicycle, resting on these rollers, may be driven by a rider just as he would drive it on a roadway, but, instead of moving forward, its wheels will simply revolve on the wooden friction rollers, which are nothing more than roller bearings. Pedal as he will, the rider, with his machine, will remain stationary in a relative sense, though they may cover the practical equivalent of many miles' distance.

THE remarkable amount of distortion that a well-made corrugated boiler furnace can undergo without leading to a disastrous explosion is very well illustrated in the sketch on this page, which, with the diagram opposite, has been taken from *The Locomotive*, published by the Hartford Steam Boiler Inspection and Insurance Company. The accident in question, as detailed in that publication, took place in one of the four compound marine boilers of the whale-back steamer *City of Everett*, which is used as a freight steamer in the coasting trade between San Diego, Cal., and British Columbia. The *City of Everett*



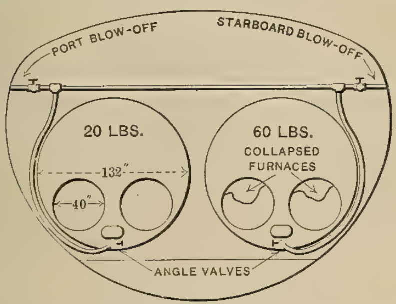
A COLLAPSED FURNACE FLUE.

was built of steel in 1894, at Everett, Wash., and is 346 feet in length, 42 feet 8 inches in breadth, and 13 feet 7 inches in depth. She has four boilers, each 132 inches in diameter and 11 feet long. The shells are of steel, 0.938 of an inch thick, and of 60,000 pounds tensile strength; and the pressure allowed by the government inspector is 168 pounds per square inch. Each of the four boilers has two corrugated steel furnaces, 40 inches in diameter and 8 feet 6 inches long. The furnace shown below is from the forward starboard boiler, both furnaces of which were burned and bulged down by blowing the water out of the boiler while there was a fire in each of them. The blow-off pipes from the four boilers are connected into cross, or thwart-ship blow-pipes, which pass over the tops of the boilers as shown opposite and are provided with valves on the port and starboard sides of the vessel. It is this arrangement of the blow-pipes which led to the accident.

IT appears that the vessel was loaded in British Columbia with coal, and after leaving Victoria, and while steaming across the straits of San Juan de Fuca, the engineer in charge ordered the water tender, or fireman, to blow down three or four inches of water from the forward starboard boiler. In carrying out this order the fireman opened the valve on the front head of the starboard boiler, and also the outboard blow valve on the starboard side. This will be understood by reference to the sketch opposite. After blowing down as far as desired, the top outboard valve was closed. This, of course, stopped the blowing at once; but when the man came down from the ladder he forgot to shut the lower valve, on the head of the boiler. When the steamer reached Port Townsend, one of the breeching bolts on the forward port boiler was found to be leaking, and the chief engineer therefore ordered the pressure to be lowered on that boiler, and that water blown out, so that the bolt could be renewed. He also gave orders to wash out the two after boilers, and carry steam only on the forward starboard boiler. As the *Everett* was to lie at the dock over night, a slow fire was kept under this boiler, the fires under the other three being

hauled. When the steam pressure on the three cooling boilers had been reduced to about twenty pounds, orders were given to open the blow-off valves attached to them, and blow down. This was done, the blow-off valve on the front head of the starboard boiler being open all this time, although it was supposed to be shut.

THE result hardly needs to be told. The boilers from which the fires had been drawn were under only twenty pounds of steam, while the forward star-



THE BOILER CONNECTIONS.

board boiler, with a fire in each furnace, was carrying sixty pounds, so that it emptied itself much more rapidly than any of the others. After some little time one of the firemen opened one of the doors of the forward starboard boiler, and found the furnace red hot and bulged down, as shown in the engravings. Upon investigation he found the other furnace in this boiler in the same condition. The fires were at once hauled out, and upon examination it was found that the furnaces were down twenty-one inches, the corrugations being pulled out so that at the bottom of the bulges the furnace was almost smooth; but no signs of fracture could be discovered. If these furnaces had been poorly made, or if they had been constructed of a material deficient in ductility, it is almost certain that a disastrous explosion would have followed the rough usage to which they were subjected; and this fact ought to satisfy any one of the paramount importance in boiler construction of having good material and good workmanship. The unwisdom of giving a fireman too many things to remember will also be apparent; for if each boiler had been provided with its own separate blow pipe, discharging directly into the sea without any connection with the other boilers, this accident could not have happened.

"THE line shaft a relic of the past! Decidedly not!" So the transmission engineer probably said to himself on reading the little item in these pages last month concerning shafting friction and independent driving for machines. The whole trouble with line shafting, he may add, and that very properly, is that too many incompetent people think they know how to make it and how to put it up. In truth, however, a line shaft is a comparatively delicate piece of machinery, and its making, erection and maintenance all require good engineering sense. With this its friction ought to fall far below that which many experiments have shown to exist. But the average line shaft, it must be remembered, is a wriggling, squirming body, trying hard to preserve a straight line against the evil efforts of uneven bearings and injudiciously placed driving pulleys. To the superficial eye the conditions may appear right enough; the shaft is a patient sufferer and its only protest is found, disguised, in the coal bill. What may be accomplished in the saving of shaft-bearing friction is shown very strikingly in the article on "Roller Bearings for Machinery," which appears elsewhere in this issue. In this, one case is cited where the power necessary to drive shafting, running in babbitted bearings, amounted to over 62 per cent. of the total power delivered by a water wheel, while with the adoption of roller bearings a reduction was made of a little more than 17 per cent. Under both conditions, however, it is safe to assume that the alignment of the bearings might have been improved, or their spacing and the position of the pulleys on the shaft changed for the better. These are matters of detail which rarely get a

proper share of attention. So long as there is no positive squeak, no plainly evident mark of something wrong, the shaft is permitted to go on in the old way. Into competition with this ill-cared-for machine comes the new system of independent driving, upon which all possible refinements of practice have been lavished. "Is it to be wondered at," asks the transmission engineer, "that there should be a glaring contrast between the two? Give the old shaft a chance!" A fair chance, indeed, it deserves. For some purposes and in some places its usefulness may have come to an end, but it still has merits from which ignorance and carelessness should not be permitted to detract. Shafting honestly made and intelligently put up and cared for can give a good account of itself.

WITH the constant agitation in favour of mechanical stoking, renewed attention should be given to the more general use of producer gas for ordinary boiler firing. More than thirty years ago the veteran John Bourne, in discussing this subject, wound up by saying, "On the whole, gas furnaces promise best," and this promise to-day is still before us. The possibility of utilising the most inferior grades of fuel is one consideration which makes the gas generator a possibility where the mechanical stoker is ruled out. The nuisance accompanying the formation of clinker and scaffolds in the older types of gas producers has been practically obviated in the recent forms of producers in which the fuel bed is kept in constant agitation, and there seems to be no good reason why the gas producer should not soon form an essential element in every power plant of medium and large size.

THE utilisation of natural forces, such as the tides, wave power, wind, and others, seems, at the present stage of the problem, to depend more upon the advent of some successfully efficient method of power storage than upon the question of immediate details. In this respect it is somewhat like the early experiments for the use of steam as a motive power, in which, before the rotative engine was practically applied, numerous plans were made to pump water by apparatus of the Savery type and then permit the water to flow upon a water wheel. The persistent efforts which are being made to harness wave power will probably depend for their final success upon the arrival of the successful scheme for power storage. Just what form this will take cannot now be predicted; possibly chemical, as in the storage battery, or mechanical as with compressed air; but in any case it must be efficient, not bulky, and at the same time prompt to respond to sudden drafts of power. When such a storage device appears, the commercial control of natural sources of power must be but a question of brief time.

AMERICANS have been constantly reminded of their barbarity in permitting the use of the overhead trolley, and have been told of the greater civilisation of the countries of the old world, where no such unsightly intrusion is permitted; but the trolley now seems to be making its inroads in France and Germany with remarkable rapidity. Even in Paris overhead wires are being talked of for the transportation facilities of the coming exposition of 1900, and in the provincial cities of France, as well as in the great majority of the cities of Germany, the American system seems to have gained a firm hold. That the overhead wire is unsightly, is not to be denied, and ultimately, no doubt, it will have to give way to some less objectionable form of power communication; but that is a necessary intermediate stage of the solution of the rapid transit question, must be admitted whether the admission be welcome or not.

UNITED STATES CONSUL DOBBS, writing a short time ago from Valparaiso, in Chili, on the careless manner in which goods for export to that coun-

try are packed by American manufacturers, emphasised practically what was said in these pages last year on the contrasting methods followed by British and American machinery builders in preparing their products for far-off shipment. The British shipper, true to national traits, is substantial in what he does; there is nothing flimsy in the way in which he prepares the machine which he proposes to send a thousand miles away from home, and the result is that it reaches its destination in proper condition for sale or service,—no parts broken, no parts missing. With the average American exporter the conditions are practically reversed. The packing and shipping of the goods are of the happy-go-lucky order; more faith is put in Providence than in stout timbering and boxing, and the result is, generally, trouble at the other end of the line, an exasperated purchaser, and a mental resolve on his part to buy from some one else in the future.

CONSUL DOBBS writes of miscellaneous goods, not machinery particularly, but what he says fits this quite as well. "Many packages," he remarks, "often come in very thin boxes, without any protection in the way of wire or sheet iron bands, nailed with short wire nails, easily drawn, and the Chilian longshoreman or lighterman, expert in the use of the short, strong knife he carries, often makes a nice plunder right under the eyes of the officers of the steamers. Then, again, in heavier articles, which offer no temptation to theft, the cases are not strong enough to withstand the very rough handling they receive. The peon likes to see a good smash, and not only handles the cases roughly, but if he is not watched will deliberately drop a case in such a way as to smash it, just to see it break, and with the same enjoyment that a small boy throws stones through a window. Whenever possible, packing should be done in such a manner that the package could not be broken open by ordinary means, or by being dropped. A case in point occurred the other day. A lot of miscellaneous bronze and brass repairs for mining machinery came in what was a little stronger than a cracker box. It broke open in the ship's hold, and certainly many small parts were lost, probably some of them of vital importance. A peon was detected in carrying off some small castings in his bundle, not that they were of any use to him, but simply, apparently, for the sake of stealing."

THE connection between the use of mineral oil in marine boilers and collapsed furnaces was discussed at some length in one of the late numbers of *Engineering*, of London, and several interesting points were mentioned to indicate the part which the oil plays in bringing about trouble. Mineral oil, in the charred or semi-charred condition in which it occurs on furnace crowns, probably partakes more and more of the non-conductive properties of its near relative, hard paraffine. "If," says *Engineering*, "we compare the thermal conductivity of iron, plaster of Paris (*i. e.*, sulphate of lime or ordinary boiler scale), and paraffine, we find the relation to be as 100 to 1 to 0.01, or, in other words, a ¾-inch steel plate would offer as much resistance to the passage of a certain quantity of heat as $\frac{1}{133}$ inch of plaster of Paris, or $\frac{1}{13300}$ inch of paraffine, or a film of paraffine of $\frac{1}{1000}$ inch thickness would offer as much resistance to the passage of heat as we might expect from a steel plate 10 inches thick. Now no man in his senses would expect to get satisfactory results from a furnace plate 10 inches thick, for even although it would be too strong to collapse, it would most certainly burn. But there are other matters to be taken into account. Furnace tops which have collapsed in consequence of the presence of oil are invariably found to be quite dry and not at all greasy, and, compared with the other surfaces in the same boiler, they give one the impression that the oil had been burnt away. If a sooty deposit was then formed, this has been washed away; in fact, such surfaces

usually appear of a lighter colour than the rest of the boiler, giving these parts the appearance of being covered with a sort of mildew. It is also possible that this oil has chemically united with the water or with the iron. This view is supported by the fact that the whole of the grease is removed from the furnace tops down to the level of the bars. If the removal of this scale were a question of temperature only, it would disappear in patches, and thus, by allowing the water to return to these points, the plates would be kept cool and be prevented from collapsing ; but evidently the oil remains in position and acts as a non-conductor until the plate has given way, and it is only then that the oil disappears from off the whole surface.

"One of the most inexplicable phenomena in connection with such collapses as those of which we speak," *Engineering* continues, "is that it is rare to find only one furnace in a boiler which comes down, or to find only the furnaces of one boiler collapsed ; almost invariably all the furnaces of all the boilers of the steamer come down together. In such a case one naturally turns to the water, expecting it to have undergone a uniform change in all boilers, but it will be found to contain neither salt nor oil, or at least only such inappreciable quantities that they do not reveal their presence to the taste, in which respect this water differs from condenser water, which has a distinctly oily flavour. The only plausible explanation of such general collapses is, that the oil which causes the trouble is that which the water has dissolved, and which no filter can catch ; that it gradually and uniformly covers the heating surfaces, which slowly grow hotter and hotter, all the temperatures rising practically at the same rate. When a point is reached where the reduced elastic limit of the steel coincides with the stress due to the steam pressure, a sudden increase of this pressure, which would, of course, affect all furnaces equally, brings them down together.

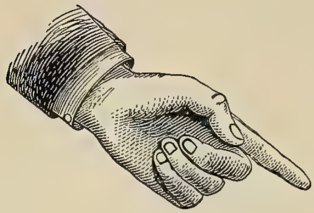
"Another feature of boilers whose furnaces have collapsed is that many of the internal seams and most of the stays and tubes will be found to be leaking, indicating that these parts have been generally overheated, for the tendency of iron and steel is to return to its original form during any annealing process. The expanding of the tubes and the caulking of stays and seams being done cold, all these edges tend to open out on being heated, and as these troubles are far more frequent than collapsed furnaces, the question naturally arises, How can this overheating be prevented ? As it is due either to oil or to scale, these should not be allowed to accumulate in the boiler, but if they have found their way in, they ought to be removed. Scaling is the means adopted for the one, but oil is not so easily dealt with. Petroleum might perhaps remove it, but cannot be practically applied on account of its inflammable nature. Soda will not attack hydrocarbon oils. Salt water is said to be more efficient, but if sea water is meant, then evidently it is not the salt, but the scale which has a beneficial influence. It should be allowed to accumulate, much blowing down and refilling with salt water being resorted to, and then, on scaling the heating surfaces, the grease will be detached with the scale."

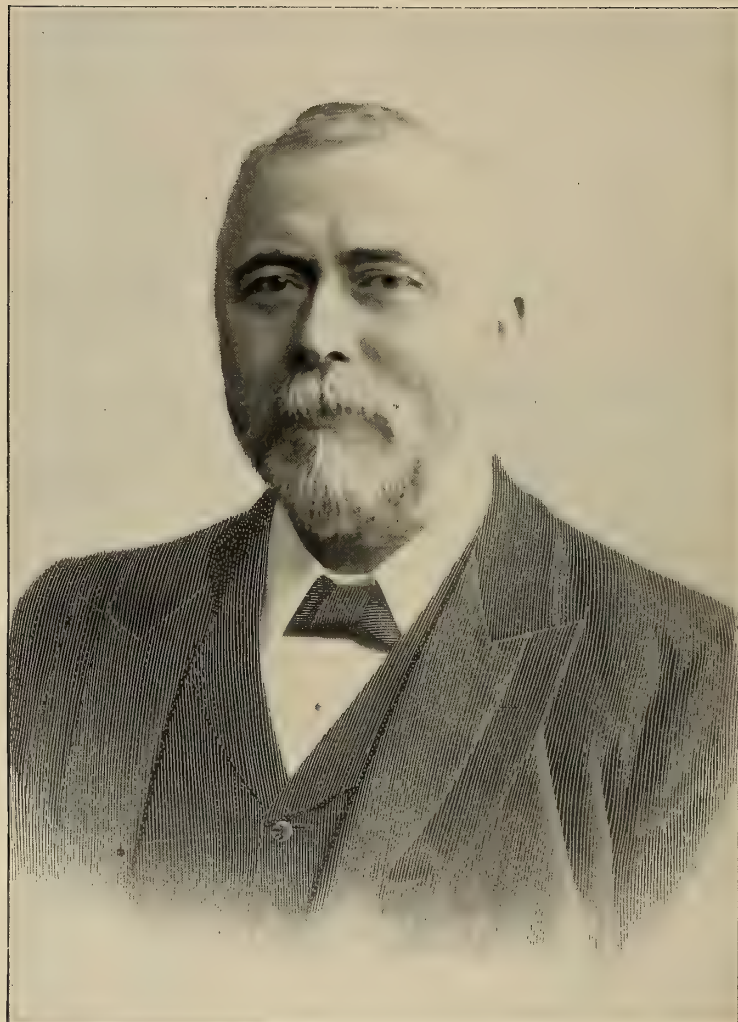
PRICE, 25 CENTS. $3.00 PER YEAR. PUBLISHED MONTHLY.

Cassier's Magazine—June, 1897.

CONTENTS.

$3.00 per year. 25 cents per number. Entered at the New York Post-Office as second-class matter.





FROM A PHOTOGRAPH BY BYRNE & CO., RICHMOND.

W H White

DIRECTOR OF NAVAL CONSTRUCTION AND ASSISTANT CONTROLLER OF THE BRITISH NAVY.

CASSIER'S MAGAZINE.

VOL. XII. JUNE, 1897. NO. 2.

AMERICAN INCLINED PLANE RAILWAYS.

By Samuel Diescher.

INCLINED planes were known probably as long since as mining was pursued in a rational and extensive manner, and were used to lower the products of mines, situated on elevations, to the roads, rivers and mills in valleys. To-day scores of them can be seen in action along the slopes of the river valleys of the bituminous coal regions of Pennsylvania and West Virginia in the United States. But it is of comparatively recent occurrence that they were employed also in the transportation of people, teams, electric cars, etc.

The inclines found about mines, as a rule, are so-called "gravity inclines," which designation is derived from the fact that they are operated by the force of gravity, being employed not to raise, but only to lower, a load, whereas those in passenger and other service chiefly referred to in this article, are operated by power plants especially constructed for this purpose. Most of the inclines of this latter type are located at Pittsburgh, Pa., and Cincinaati, O. The reason for their existence and popularity there is that both cities are hemmed in by a crescent of hills, and the area for building purposes is not very extensive. Both of these cities have so grown that most of the ground on the lower levels has been taken up by commercial and industrial establishments, and since ground, demanded for such purposes, commands a higher price than could be obtained for it if used for dwelling purposes, people in search for building sites had to look beyond the business portions of the cities for them.

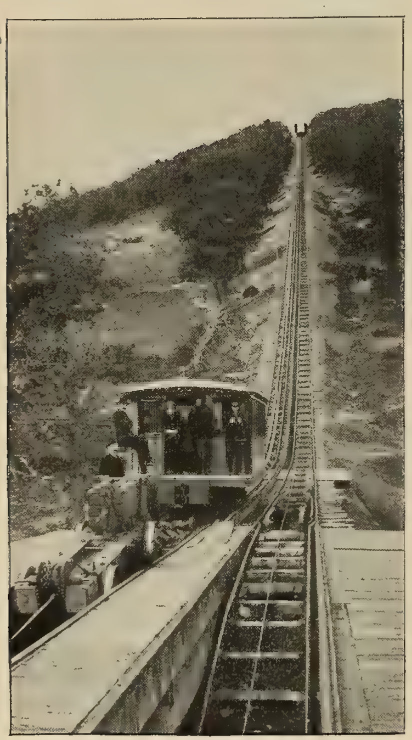
The hills surrounding Cincinnati are on the average about 300 feet above the general city level, and those at Pittsburgh are about 400 feet high, and in both cities large areas of moderately rolling ground are found on these hills, admirably adapted for residence sections of large centres of population. In both cities the higher sections are accessible by way of circuitous roads, but their grades are too steep, as a rule, for foot travel, and rides on them, for same reason, are too tedious to be pleasant. This, with the difficulty of transporting large crowds almost simultaneously during the morning or evening hours, when most people are going to, or returning from, their daily pursuits, suggested the employment of means by which transportation in either direction could be

established between the hill top region and the city with the least expenditure of time and money.

As a matter of course, the solution of this problem was found in inclined planes, because they permit the most direct and, therefore, the shortest connection between the foot and the crest of a hill. In this way an elevation of from 300 to 500 feet may be ascended in from one to two minutes, while by any other mode of travel ten and perhaps twenty minutes would be required.

There are two essential features about inclines that recommend them, from a commercial point of view:—

First, the distance between two termini being the shortest possible, re-



THE MOUNT PISGAH PLANE AT MAUCH CHUNK, PA.

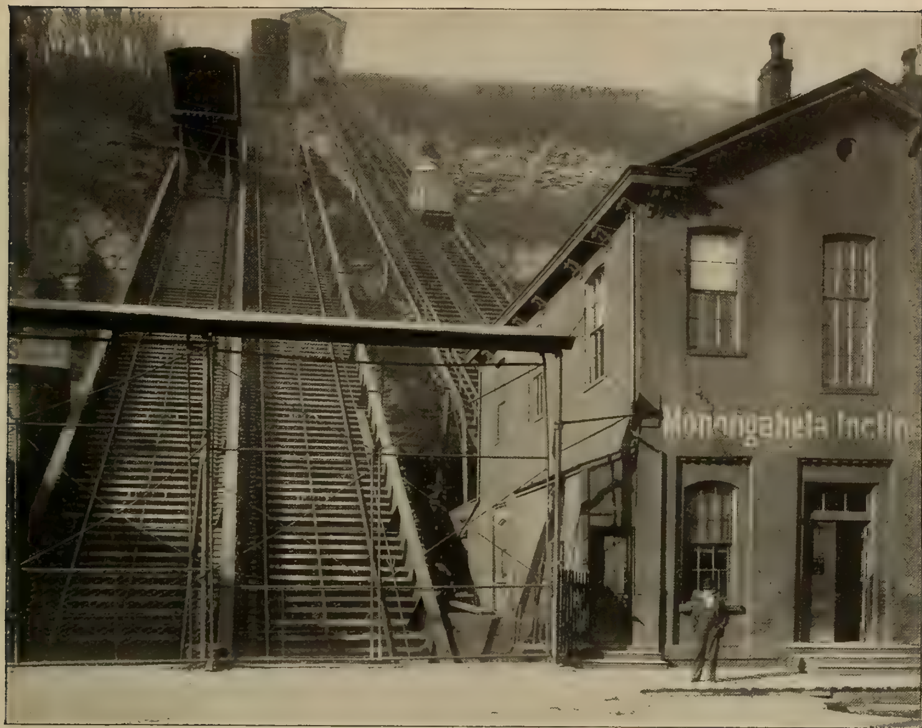
quires the least time to be travelled over, and therefore more trips can be made in a given time than on any competing route not perfectly straight.

Second, on an incline, having always double tracks, and the cars running in opposite directions, the dead weights counterbalance each other, eliminating thereby all the losses due to the transportation of the cars, motors, etc. Thus, none but paying loads are hoisted by the power plants.

Another feature may be added to these, namely, that an increase in the hoisting capacity of the inclined plane does not affect the operating expenses in the same ratio, for if the capacity were doubled, in any particular case, it does not follow that the number of employees too must be increased; such modifications affect principally the fuel consumption, but scarcely any other item of current expenses. In conformity with the foregoing, there results from the employment of an inclined plane within the route of a passenger railway, not merely a saving in time and equipments, but also, to a very considerable extent, a saving in the cost of operation of a whole line of passenger railway. In both the cities named, several of the electric street railways use inclined planes as links by which they establish continuity between their low-level and high-level divisions. In some cases the electric cars with their passengers are taken up the inclines, and in others the passengers are transferred from the electric cars when approaching the incline and again from the incline to the electric cars to continue their ride.

Of Cincinnati it can be said that by the installation of her inclined planes large and pleasant suburbs have been created in regions that were, prior to the time of this means of transportation, occupied by truck gardens, or were entirely unused.

The oldest inclined plane in America, and probably the oldest in the world, engaged in the transportation of passengers, is the Mount Pisgah plane near Mauch Chunk in the Lehigh Valley, Pa. One of the peculiarities of this plane is that the ropes are not hitched to the passenger car, but to a special car or truck, known in the anthracite region by the name "barney." This truck acts as a pusher against the passenger car. It is on the lower side of the car,



MONONGAHELA INCLINES AT PITTSBURGH, PA.

and thus, when the hoisting machinery is brought into action, the barney is pulled up and, in turn, pushes the car ahead. There is a peculiar arrangement on this barney that should be mentioned, namely, instead of two axles it has four half axles, each with a wheel mounted on it, and these axles are so attached to the truck frame that the wheels may be brought closer together and thereby the gauge reduced, or they may be spread for a wider gauge, as the situation may require.

From the illustration on the opposite page it will also be seen that the barney does not stand on the same track as the passenger car, but on a track located within a sloping trench, and that the track in the trench is considerably narrower than the track on the incline and also on the ground level upon which the passenger car stands. It will further be noticed that at the point where the slope begins there is a switch by means of which the wheels of the barney are adjusted to suit the gauge of one or the other of the tracks upon which it is to enter.

When the barney descends into the trench to a depth where it disappears below the ground level, the passenger car is free to move back from the inclined plane. The purpose of this arrangement is to avoid the necessity of permanently hitching the rope to the passenger car, because this latter is not only to travel on this plane, but to continue its journey on two other planes, all of which, combined with several gravity inclines, constitute a circuit by which the tourist travels over three inclines and three intervening slight down grades, starting with the ascent of the Mount Pisgah plane and finally returning to Mauch Chunk by way of a gravity plane from Mount Elias.

Considering the relative positions of the car and barney, as represented on the picture, they are just ready to start upon the ascent of the plane. The

THE PENN INCLINED PLANE AT PITTSBURGH.

barney, on account of being still on the lower track, is not quite in touch with the rear bumper of the car, but will be so when both are on the same track.

Another feature of interest is the safety device employed for the prevention of accidents in case the hoisting rope should break. This device consists of a rack laid between the two tracks, extending over the whole length of the plane, and a pawl, automatically thrown into the rack by which the car is held fast upon the track in case the rope should give way.

The rope consists of a number of small strands of steel wires, which are laid parallel to one another and interlaced with wire, thus forming a ribbon about seven inches wide. This is wound upon a wrought iron drum driven by a pair of 240 horse-power engines. The length of the Mount Pisgah plane is 2323 feet and the total rise is 664 feet. The plane is used mostly by tourists, and its passenger business therefore is confined principally to the warm season.

The second oldest inclined plane in America is the Monongahela passenger incline, located in Pittsburgh, Pa. This was opened to travel in 1870. It is 640 feet long and has a total rise of 375 feet, its grade being 71½ per cent. The cars are each seven feet wide and fifteen feet long, divided into two compartments and a platform, surrounded with iron railings. The seating capacity of each car is thirty people and there is standing room for fifteen people, so that the total capacity is forty-five passengers. About 1,600,000 passengers are carried annually. The plane runs day and night.

The Monongahela Inclined Plane Company also operates a team incline alongside of the passenger incline. As to grades and length they are alike. The freight cars are each 17 feet wide by 32 feet in length. The hoisting capacity is about 20 tons. This plane has been operated since 1884. The cars each accommodate two heavy two-horse wagons or one four-horse wagon with the front horses turned sidewise. The running hours of the plane are from 7 A. M. to 7 P. M., during which time generally about 250 teams are transported.

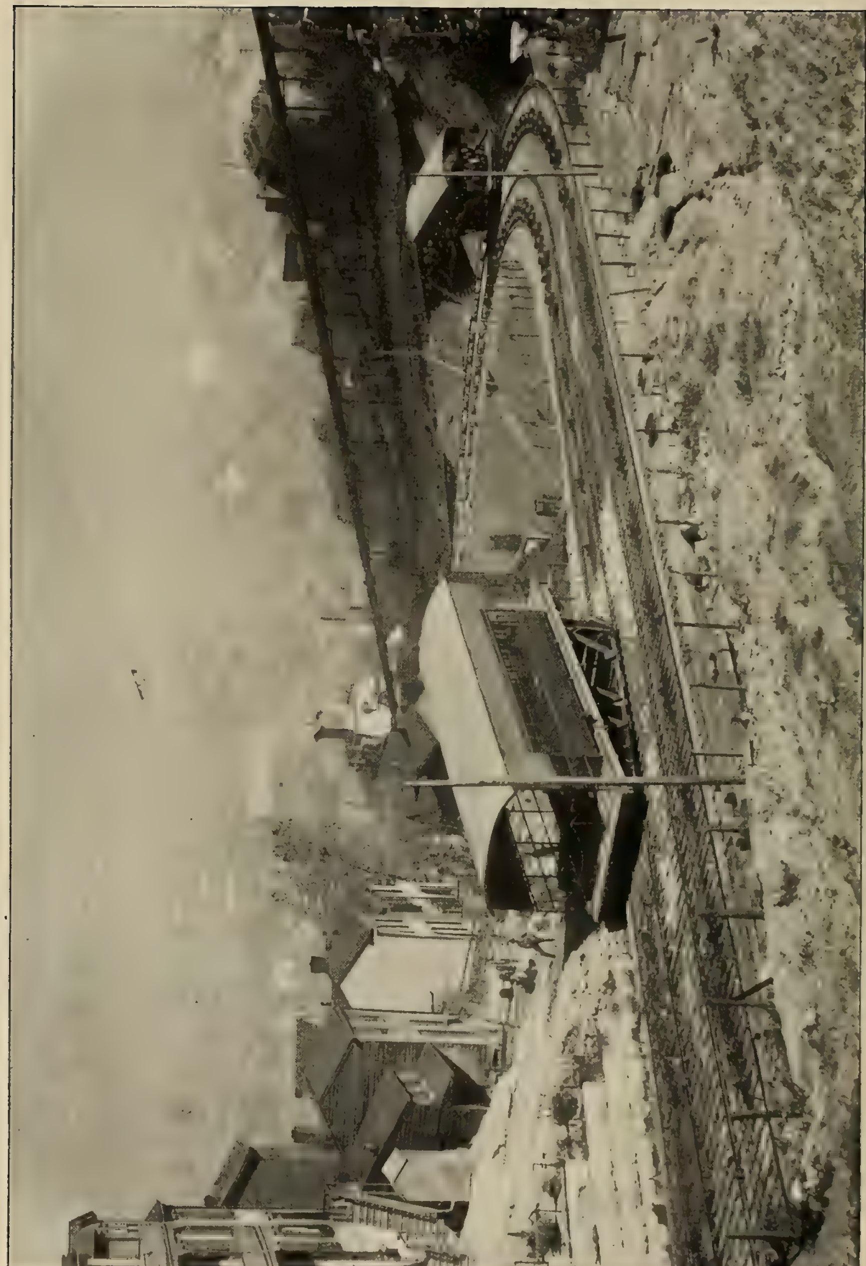
The Penn incline, also in Pittsburgh,

was built during the years 1882 and 1884 and was opened to travel on March 1 of the latter year. It was constructed with the view of hoisting 20-ton railway freight cars to the hill top. The purpose of this plane was the establishment of a coal yard on the hill top. Owing to the steep roads that lead to this section, coal was delivered there during the winter season at from one to two cents more per bushel above the price asked in the lower part of the city. As an empty freight car of 20 tons capacity weighs about 10 tons, the hoisting capacity of this incline was made equal to 30 tons against an empty car on the down grade, and with respect to this performance the whole of the incline was constructed. The incline cars are each 16 by 40 feet and weigh 30 tons when empty. There are two hoisting ropes of 2¼ inches diameter to each car, and a 2-inch safety rope is fastened to both cars. The aggregate ultimate strength of the two hoisting ropes for each car amounts to 300 tons when new, and about half as much when thrown out of service. Thus, their least aggregate capacity is about 150 tons, or about six times the greatest strain brought upon them.

The object in discarding the ropes while they still have a strength of six times the strain acting upon them is to provide an ample margin of safety in the case that one or two of these ropes should happen to break. This, however, has never occurred on an inclined plane in passenger service in these regions, on account of the close inspection exercised. The length of the track is 840 feet and the total rise, 335 feet. The main span of bridge work, reaching across the yard tracks of the Pennsylvania Railroad, is 232 feet. The plate-girder span next to the main span is 120 feet and the remaining spans are 60 and 40 feet, respectively.

THE DUQUESNE INCLINE AT PITTSBURGH.

In addition to the Penn and Monongahela inclines there are in Pittsburgh the following:—The Duquesne incline, for passengers, 780 feet long, total rise 400 feet, and a grade of 58.5 feet in 100 feet. The hoisting capacity is forty people. Mount Oliver incline, 1600 feet long, and 375 feet high. Knox-



THE KNOXVILLE INCLINE AT PITTSBURGH.

ville incline, 2640 feet long, and 375 feet high. St. Clair incline, 2060 feet long, and 361 feet high. Fort Pitt incline, 350 feet long, and 135 feet high. Castle Shannon incline No. 1, 1375 feet long, and 451 feet rise. Castle Shannon incline No. 2, 2112 feet long, and 185 feet rise. Troy Hill incline, 370 feet long, and 160 feet rise. Nunnery Hill incline, 1100 feet long and 300 feet rise.

In all there are ten inclines in operation in Pittsburgh and two in its sister city Allegheny. The greatest single load hoisted up the Castle Shannon incline No. 1 was a 20-ton locomotive belonging to the narrow gauge railway connected with incline No. 2 and operated by the same company. The illustration on the opposite page represents the middle portion of the Knoxville incline, with both cars passing the curve which is the characteristic feature of this plane. In the background of this picture is seen the elevated iron track construction of the Mount Oliver incline already referred to. The Nunnery Hill incline was the first incline built with a curve. Its elevated structure is of wood and is soon to be replaced by steel construction.

The city of Cincinnati, having six inclined planes, ranks next to Pittsburgh in regard to number. Of these, five are arranged for teams and passengers, and one is for passengers only. The Price Hill Incline Company owns and operates two inclines in the West End of the city, one carrying teams and the other passengers. Owing to the fact that these inclines run side by side, their general dimensions are alike, namely, length 800 feet, total rise 350 feet and grade 44.66 in one hundred feet.

The passenger incline has a capacity of sixty passengers. Its safety and hoisting ropes are both 1¼ inches in diameter. The capacity of the freight incline is 20 tons, and the safety and hoisting rope are 1⅜ inches in diameter. The general appearance of these inclines is shown in the illustration on page 93.

CASTLE SHANNON PLANE NO 1. AT PITTSBURGH. SEEN FROM THE UPPER LANDING.

The safety devices of these inclines are somewhat different from those of other inclines. There is a large sheave at the head of the incline and of a di-

END VIEW OF A CAR ON CASTLE SHANNON PLANE NO. I.

ameter equal to the distance between the centres of the two tracks. The safety rope, of which one end is hitched to each car, in the usual way, passes around this sheave. The journal bearings are so arranged that the sheave will slide forward bodily in case there should be any unusually heavy pull on the safety rope. By the forward motion of the sheave its flanges are automatically pressed together by means of stationary jaws or wedges between which are the flanges. In this manner both the rope and the sheave are clamped and brought to a standstill.

The first incline in Cincinnati was operated by the Cincinnati Incline Plane Railway Company. It leads to Mount Auburn, a suburb of that city. It was first put in operation in 1872 when it was used for passengers only. It has since been remodeled and is now employed for passengers, electric cars, etc. The total length of this plane is 860 feet, with a grade of 30 feet in 100 for the first 250 feet, and 20 feet in 100 for the rest of the length. The safety and hoisting ropes are both 1¼ inches in diameter and the lifting capacity is 20 tons.

The other three inclined planes, operated by the Cincinnati Inclined Plane Railway Company, are all used for hoisting electric cars, teams and passengers. They are the Mount Adams, Belleview and Fairview inclines and are

respectively 999, 1032 and 674 feet long, with total rises of 268, 300 and 210 feet, and average grades of 29.6, 32.25 and 35.15 feet in 100. The hoisting capacities, with the descending car empty, are 20, 15 and 10 tons. The maximum speed on all three is 700 feet per minute. Each of them employs two hoisting ropes per car, 1¼, 1¼ and 1⅛ inches in diameter. The safety ropes are 1½ inches in diameter throughout.

Among other American cities in which inclined planes have been built may be mentioned Duluth, Minn.; Johnstown, Pa., and Wheeling, W. Va. The Seventh avenue incline in Duluth was put in service in 1892. Its track work is 2975 feet long, all built on elevated steel structure. Its grades vary from 23⅓ feet in 100 at the lower end to 15 feet in 100 at the upper end. There are two Corliss engines, directly connected with the drums, which are of the cable railway type. The plane extends from Superior street, the principal street in the city, to the hill-top north of the city. The total rise is 510 feet. The hoisting capacity is 25 tons, with an empty car coming down. The cars are 16 feet wide and 40 feet long and have, each, a passenger cabin, 6 feet wide and 24 feet long. The greatest number of passengers hoisted at any one time was 407 on a day on which over fifteen thousand people availed themselves of the incline. The plane is owned and operated by the Duluth Street Railway Company of the same city.

The Cambria incline at Johnstown, Pa., is another very interesting incline. It was projected after the great flood in June, 1889, and within thirty days after the occurrence of that disaster, steps were taken toward its construction. This was suggested by the low and rather damp location of that town, on account of which the cellars under the houses were frequently filled with water, seeping through the ground from beneath. The length of the plane is 895 feet, its total rise 581 feet and its grade is about 72 feet in 100. The view from the upper landing is one of the finest in the State of Pennsylvania. As seen in the illustration, on page 94, the lower end of the incline is approached by way of a bridge across Stony Creek, of about 300 feet span. This is reached by a wooden trestle structure rising gradually from the general level of the town. The cars are each 12 feet wide and 24 feet long. Owing to the steepness of the grade, the space under the rear end of the car is so large that it afforded ample room for the insertion of a passenger cabin which is accessible by stair-

ON CASTLE SHANNON PLANE NO. 2, PITTSBURGH.

ways at both stations. The platform is well guarded by strong wrought iron railings and stout booms that form a very strong barrier against the backing off of wagons in case the horses should become nervous.

The Mozart Park incline in Wheeling, W. Va., was built for passenger travel only. The grade is 50 feet in 100, length 940 feet, and total rise 420 feet. It establishes communication between the city level and Mozart Park, which is situated on the hill. As there are no dwellings on the hill and the buildings there are solely for entertaining the people visiting the park, this plane is operated only during the warm season, when it is pleasant to be in the open air. During the winter months it remains closed. The structure supporting the tracks is of steel and the whole plant is carried out in a very substantial manner. It was opened to travel in 1893 and is owned and operated by the Mozart Park Association, of Wheeling, W. Va.

The roadway of inclined planes consists, generally, of two tracks, with grades ranging from about 10 feet in 100 to almost a vertical ascent. As a rule, two cars are employed and each of these travels forward and backward alternately, remaining, however, on its own track. The cars are hauled by steel wire ropes, set in motion by stationary winding machinery, located, in most instances, at the upper terminus of the incline. The connections between cars and ropes are permanent, and the cars are so constructed that their floors are in a horizontal position throughout the whole trip. In cases where the grade of the track is not uniform, but variable, the cars are designed to suit an average of the extreme grades. The rails are generally 60-pound T rails of ordinary sections. The gauges vary from 40 inches to 10 feet, the latter being adopted on nearly all of the team inclines in Pittsburgh.

As mentioned before, the hoisting plant is located at the upper end of the plane, where also any special safety appliances for the purpose of greater security are situated. At the foot of the plane the tracks extend into a pit in which the cars recede until their floors are brought level with the floor of the station. Likewise, the floor of the car at the upper end is brought to the elevation of the landing floor. The ropes are so adjusted that the cars arrive simultaneously at their respective landings.

The control over the operation of the machinery is exercised by an engineer stationed in the cabin at the head of the incline, and so situated that he has a full view of the cars as far as local conditions permit. Of brakes there are various kinds,—steam, air, foot, hand, and gravity brakes, and there are always two, and sometimes three, installed within easy reach of the engineer. The foot brakes are used principally for checking the speed, but not for the entire stoppage of motion, for which end powerful mechanical brakes are required. Among the best adapted for this purpose are the Westinghouse air brakes, which are now in use at Pittsburgh, Johnstown, Pa.; Wheeling, W. Va., and Duluth, Minn. They are very reliable and so effective as to stall the machinery when running under full steam.

On several inclines an auxiliary throttle and a Westinghouse air brake are so arranged that they will automatically act in case a car should come closer to the edge of the upper landing than is desirable. In this event the throttle shuts off the steam from the engines and simultaneously the air brake comes into action, which results in bringing the machinery to a quick standstill. The principal object aimed at in the employment of this combination of throttle and air brake is to provide against the consequences that would follow the sudden inability of the engineer to perform his duty from any cause.

There is another air brake which is applied by the engineer at each run when the cars come to a stop. It is brought into action by a valve located at the reversing lever and the main throttle lever. On some of the freight inclines, as the Penn and the Monongahela, the reversing of the links is performed by a special small engine, because, owing to the large area of the

THE PRICE-HILL FREIGHT AND PASSENGER INCLINES AT CINCINNATI, OHIO.

slide valve, the friction under steam is too great to be overcome by a man's unaided exertion. At the Cambria incline, at Johnstown, the reversing apparatus is operated by compressed air instead of steam.

Steam brakes were found very unsatisfactory on inclines and were therefore discarded where formerly used. The trouble with them is that they are used only after intervals of from five to thirty minutes and for this reason are cold when wanted. On this account no effect is derived from the first steam as it enters the brake cylinder, because it condenses and fills the latter partly with water until the cylinder is warmed up. Owing to this circumstance steam brakes do not act with the promptness that the service demands.

LOOKING UP THE CAMBRIA INCLINE AT JOHNSTOWN, PA.

The engines employed on inclined planes are of the ordinary type, mostly of the slide valve type, preferably balanced; they are always in pairs, coupled, and with Stephenson links. In several instances automatic engines were adopted, but these, as well as compound engines in one case, do not produce any material saving in fuel, but, on the other hand, are rather a detriment to the maintenance of the plant, because every additional complication of the machinery increases its liability to derangements. As inclines in passenger service are required to run at all hours during day and night, the simpler the power plant is, the more can it be relied upon. This is a matter of vital importance because there is no time during which extensive repairs can be made.

The starting of the cars is governed by a code of electric gong signals between the conductor at the lower end of the inclined plane and the engineer in the cabin. There are three signals. The first announces that the conductor below is getting his car ready to start. This is answered in acknowledgment by the engineer. Then follows the second signal by the conductor, which means that the car at the foot of the plane is ready to start. This, too, is answered

by the engineer, and immediately thereafter the engineer gives the third signal, which means that the cars will start. Owing to the close inspection of every detail whose derangement may become detrimental to the operation of the plane, and the perfect understanding between the engineer and the conductor at opposite ends of the incline, accidents on passenger inclines have been rare occurrences.

The safety apparatus by which the safety rope is controlled, consists of two sheaves, each having three grooves and a broad brake rim for the accommodation of a steel band. These sheaves are arranged in a manner similar to the drums used in cable railway machinery, except that in the latter case the machinery or drums drive the rope, whereas in the safety device of an inclined plane the sheaves are driven by the rope which, in turn, is moved by the cars.

In both kinds of service the efficiency depends upon the friction produced between the rope and the grooves. This is attained by throwing several coils around the sheaves. If, by so doing, enough friction is produced to prevent the rope from slipping in case the hoisting ropes should break and the overweight between the two cars be thrown on the safety rope, it remains only to provide such a breaking device as will prevent the safety sheaves from revolving. This end is accomplished without difficulty by the use of steel bands, put around the brake rims already mentioned, and by means of a proper combination of levers, or chains, shaft and hand wheel. This latter being erected in the cabin, the engineer is in a position to prevent an accident in case the hoisting rope should fail.

This type of safety apparatus has been generally adopted on all inclines built since 1875. Prior to that time only a single sheave, equal in diameter to the distance between the centres of the two tracks, was employed. The efficiency of this device was not very great, because the friction produced between the rope and the sheave, extending only over half a circle, was too small to be very effective in case of a break in the hoisting rope. With a break occurring on the side of a heavily loaded car, the

THE MOZART PARK INCLINE AT WHEELING, W. VA.

latter would go down the hill notwithstanding the application of the surface brake, for this would not hinder the rope from slipping, though the sheave might be held stationary. Fortunately it must be said to the credit of the super-

NUNNERY HILL INCLINE AT ALLEGHENY, PA.

intendents of inclined planes, that ropes are never kept in service until their strength becomes doubtful, but are removed before their deterioration becomes 50 per cent. of their original strength.

The safety devices on the inclined planes in Cincinnati are the same as on most other modern inclines, but they have, in addition, a special device, the function of which is to hold the car against the upper landing in case, by a forcible collision with that landing, the hoisting ropes should be torn off in some manner. This device is known as Rancevau's patent safety hook. In construction and operation it resembles an automatic car coupling. It is so located on the track at the upper terminus that when a car comes to its landing, the hook automatically hitches to the truck frame and remains in this condition until the engineer moves the reversing lever to set the links for the next run. As long as that lever stands on the middle notch of the quadrant, the hook remains engaged to the truck, and only by throwing the reversing lever into one or the other extreme position will the car be released from that hold.

Concerning cars, there are several types in use; first, among passenger cars, the ordinary street railway car on an inclined truck; second, for steep grades, as for that on the Monongahela passenger incline, a car, divided into several compartments, entered sidewise, and each one higher than the preceding one. Among the cars for heavy service are, first, the plain car, consisting of frame work, wheels and axles, and a strong floor, guarded by stout railings on the long sides, and booms, and swinging or folding gates at the ends; second, the same car with a narrow and long passenger cabin on one side; third, on steep grades, like that of the Cambria incline, floor, railings, and other details the same as in the first case, but a passenger cabin under the main floor; and finally, a car like that first described, but with passenger accommodation on a second floor, that is on the roof over the main floor. This latter type was in use on the St. Clair incline in Pittsburgh, but for a short time only; it proved to be entirely too shaky to be pleasing to the passengers.

The frame-work of the cars is now made entirely of steel because wood is not strong enough to withstand the constant vibration under heavy strains without getting loose in the joints. Most of the heavy service cars in Pittsburgh are provided with air bumpers, similar in construction to the well known West-

inghouse air-brake cylinders, but larger in bore and stroke. Experience proved that they are more effective and more reliable and of much wider range of action than bumpers made of springs. They possess the further valuable advantage of being capable of exact adjustment to the demand of the service.

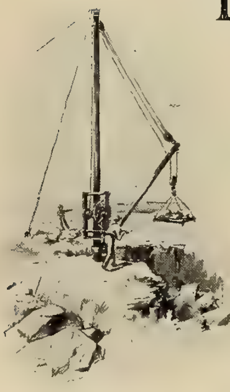
There are generally two members in the truck construction to which ropes may be hitched, and it is a rule to hitch the hoisting ropes and the safety rope to different beams, so that in case one hitching beam should be destroyed, there is another one to be depended upon. These beams, when correctly dimensioned, are of such strength that the ultimate strain of the ropes is not enough to affect them in any manner whatever.

Provisions are also made to prevent teams and cars from rolling off the car floor. Several methods are employed to accomplish this end. In some cases heavy gas-pipe booms are thrown across the ends of the floor and simultaneously heavy timbers rise from the floor to a height of about twelve or fifteen inches, and are firmly held in that position until the conductor raises the boom by which operation the guard timbers are made to sink into corresponding spaces in the floor. This device is adopted on the cars of the Penn incline and the Castle Shannon incline No. 1. On other inclines wooden booms are used, and the wheels of cars are blocked and those of ordinary vehicles are chained to the floor. Again on some, swinging gates or folding gates are used. The weights of cars used for heavy service vary from fifteen to thirty tons.

ELECTRIC POWER AT RHEINFELDEN, GERMANY.

By E. Rathenau.

Dr. Rathenau's paper was presented originally at a meeting, at Berlin, of the Verband Deutscher Elektrotechniker, and was condensed and translated for CASSIER'S MAGAZINE by Johannes H. Cuntz.



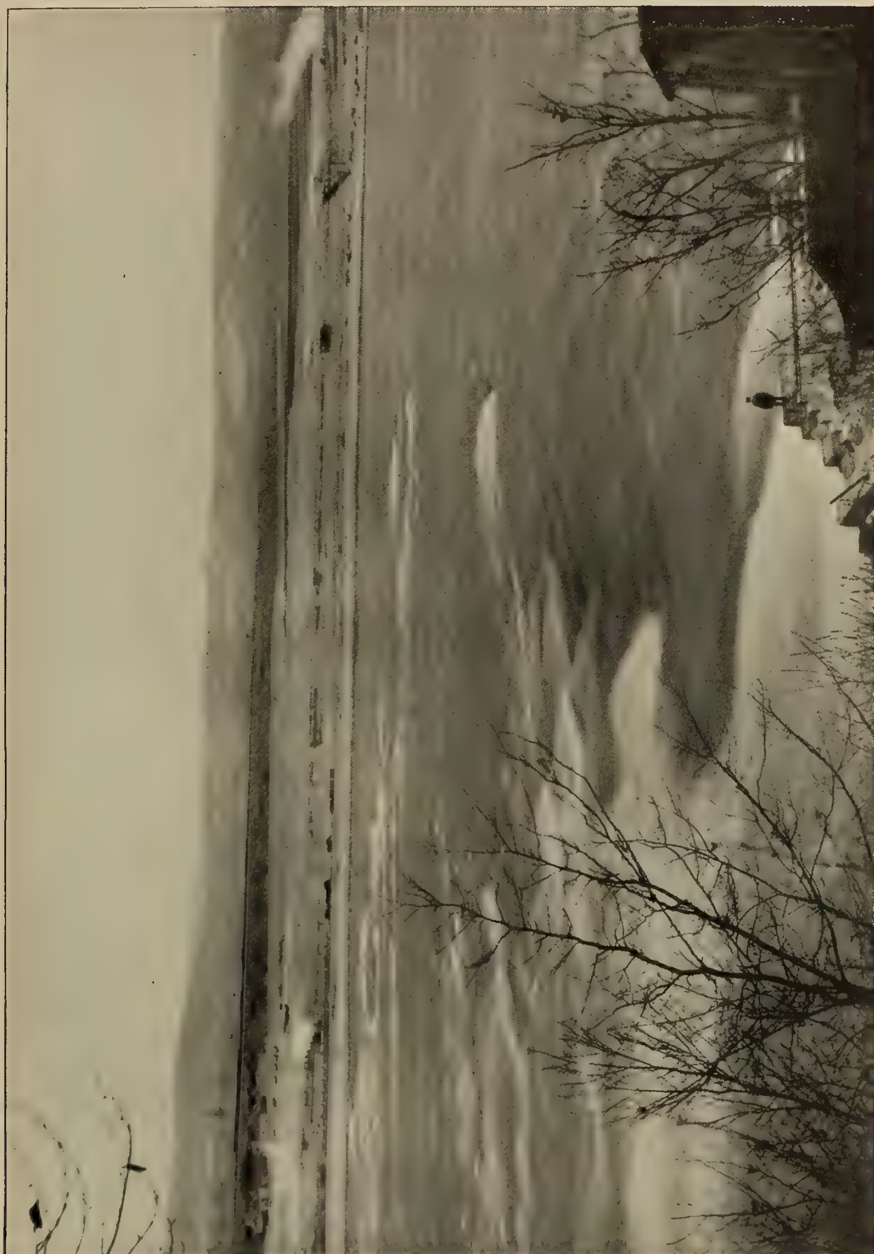
EVEN before the experimental stage of the electric transmission of power over long distances had been concluded by the success of the famous transmission in Germany between Lauffen and Frankfurt a. M., plans had been laid in that country to embody the experience gained in a plant for distributing power on the largest scale and est commercial importance.

For some time the attention of German manufacturers and engineers had been directed to the water power of the river Rhine, particularly in the upper part of its course. The stores of energy, which elsewhere must be laboriously wrung from the earth, are here in full view and are only waiting to be taken hold of and properly used. This offered an inviting field for operations, and in July, 1889, under the leadership of the Allgemeine Elecktricitäts Gesellschaft, of Berlin, a preliminary organisation was effected in order to complete the preparatory work for a water power plant at Rheinfelden, to gain the necessary concessions, to raise the capital for the undertaking, and to ensure its economical and successful operation.

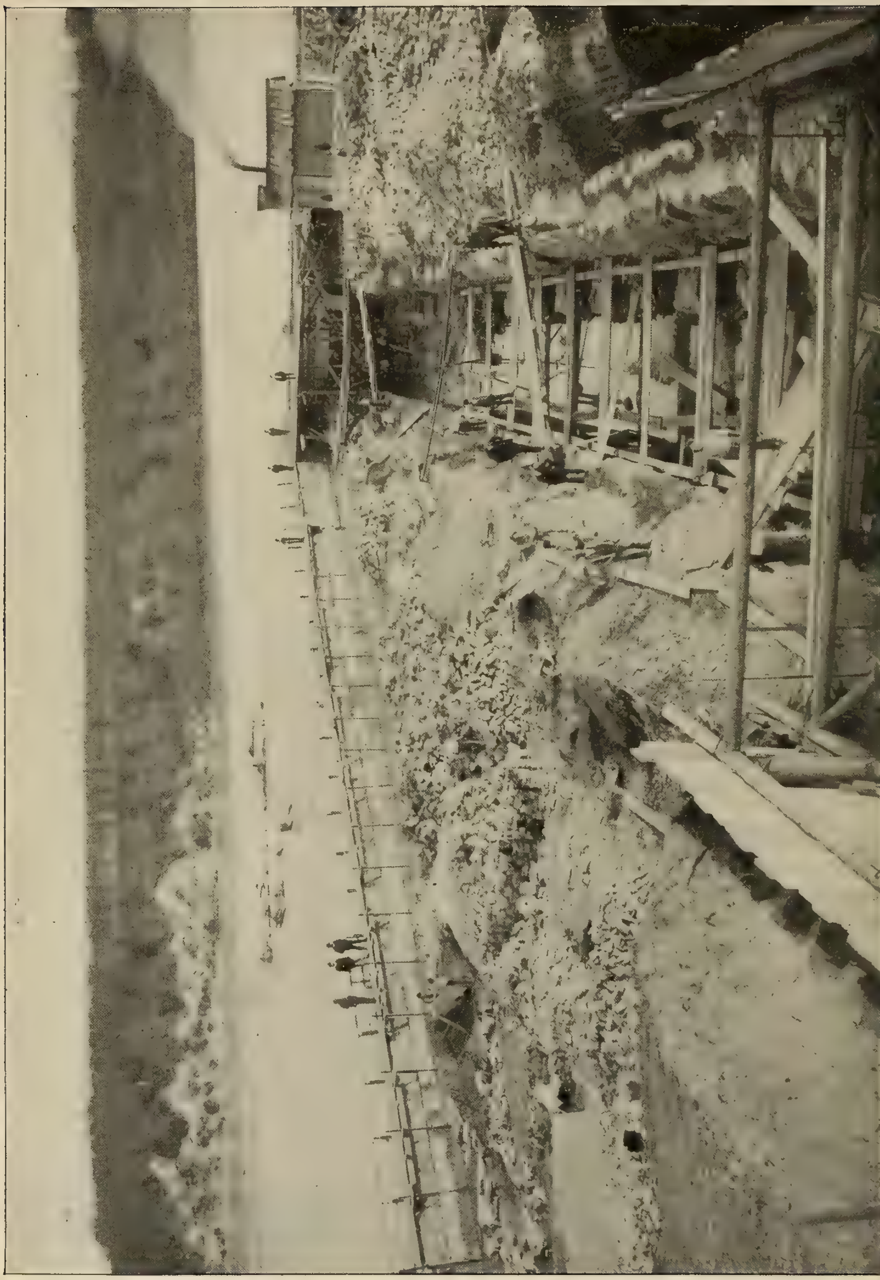
Before the end of the year representatives of the preliminary company had a conference with delegates from Baden and Switzerland, the two States bordering the Rhine at Rheinfelden, and a satisfactory basis was at length agreed upon. Among the conditions imposed upon the company was one to the effect that a flow of water of at least fifty cubic metres per second should be allowed to remain in the stream, whatever future enlargements of the plant might be made. The next step was to obtain sufficient financial backing for the undertaking, but with the general business stagnation at the time it was difficult to raise money for industrial enterprises, and it was therefore decided to utilise only part of the water power in the beginning, and to defer completion of the work to a later day. The governments whose territory was concerned granted an extension of the concessions, on condition that the necessary capital should be assured by the end of the year 1893.

In the meantime, the firms which were interested in the enterprise had investigated the plan of Professor Intze, of Aachen, according to whose calculations the commercial practicability of the project seemed assured, as the cost of installation would amount to less than 300 marks for each effective horsepower at the turbine shaft. Acting on this opinion a stock company, the Rheinfelden Power Transmission Works (Kraftübertragungswerke Rheinfelden), was founded with a capital of 4,000,000 marks. The building of the hydraulic works and the turbines was put in charge of Messrs. Escher, Wyss & Co., of Zürich, associated with the firm of Zschokke & Co., of Aarau, which intrusted Professor Konradin Zschokke with the supervision of the construction work. Professor Intze became consulting engineer for the Rheinfelden company.

The water powers on the upper part of the Rhine, from Reichenau to the



THE RHINE RAPIDS AT RHEINFELDEN.



DIGGING THE CANAL.

Lake of Constance, have been partially used by mills and textile factories, but the topography of the narrow valley offers few advantages to large industrial enterprises, and, besides this, the amount of available water varies considerably. At the Falls of Schaffhausen a greater amount of power is in evidence, but even there the flow of water is, at times, small, and its complete utilisation for industrial purposes is forbidden by æsthetic considerations.

Beyond the junction of the Aar, the flow of water becomes more constant and amounts to over 350 cubic metres per second, and as from this point on the valley widens, the local hindrances to industrial development become less and less, until they disappear entirely in the vicinity of Rheinfelden, where the river, in a distance of about 2400 metres, falls from 6.6 to 7.5 metres in a series of three rapids.

The first plan contemplated the use of this entire fall, but various difficulties arose which would have necessitated the expenditure of a very great amount of capital without a corresponding return. It was therefore decided to develop only that part of the river from Beugger Lake to Theodorshof.

The original plan was modified by Professor Intze, and on his advice the principal features decided upon were:—

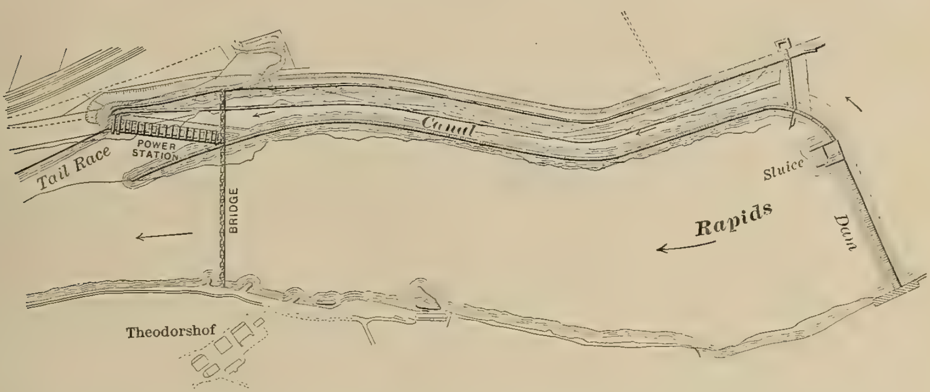
First.—An enlarged section of the head race which conducts the water to the turbines, so as to diminish the loss of head.

Second. — A longer head race and a shorter lower canal, or tail-race, which decreases the cost considerably.

Third.—The dangerous and costly roofing over of part of the tail-race, which would have been necessary if, as originally intended, fifty turbines had been installed in several rows, was avoided by placing the water wheels in one row diagonally across the canal; and

Fourth.—Reducing the number of turbines to twenty.

Fifth.—Transmission gearing between the turbines and dynamos was done away with, thereby avoiding losses of efficiency and dangers of operation. The new arrangement also made it possible to take out any turbine without disturbing its neighbours.



MAP SHOWING THE LOCATION OF THE DAM ACROSS THE RHINE, THE CANAL AND POWER HOUSE.

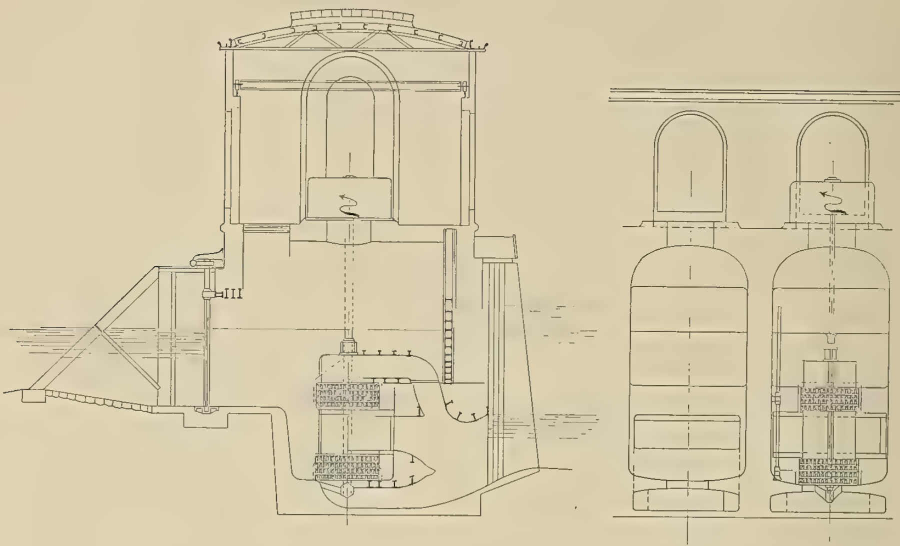
These modifications received the sanction of the States bordering on the river in April, 1895, and the technical, administrative and commercial preliminaries having been thus settled, the actual work could be begun.

Observations of the amount of water flowing in the Rhine, extending over a period of eleven years, had determined that the minimum flow was, on an average, sufficient to generate 13,800 horsepower, and each of the twenty turbines was, therefore, designed to deliver 840 effective horse-power, so that an ample

reserve above the maximum flow of 15,000 horse-power was at hand. By utilising the 2½-metre fall between the present installation and the bridge at Rheinfelden, the amount of power could be increased by 7000 horse-power.

The location of the dam across the Rhine, at the lower end of the Beugger Lake and the beginning of the upper rapids, was determined by a firm rock foundation, from which the solid masonry rises. The dam's crest is about 270 metres above sea level. There is a sluiceway, 20 metres wide, the highest point of whose sill is 1.35 metres below the crown of the dam. This sluiceway must be left open all the time on account of timber rafting and in order that there may be the prescribed flow of water, 50 cubic metres per second, in the stream. The crown of the dam is 2 metres broad and the face has a gentle slope, while the back is at a very steep angle.

The canal leading to the turbines is 50 metres wide at the bottom, which is rounded, and down the middle of which there is a gutter to carry off mud. The wall between the canal and the river is 7 metres high, 1.5 metres thick at the top and 4 metres thick at the bottom. A screen at the upper end of the canal intercepts stones and bowlders which may come down from Beugger Lake, and by opening a gateway in the wall they may be washed into the Rhine. At this point there are movable gates to regulate the flow of water in the canal, and even shut it off altogether if necessary. Above the solid rock the Baden bank of the canal is lined with masonry.



PARTIAL LONGITUDINAL AND CROSS SECTIONS OF THE POWER STATION.

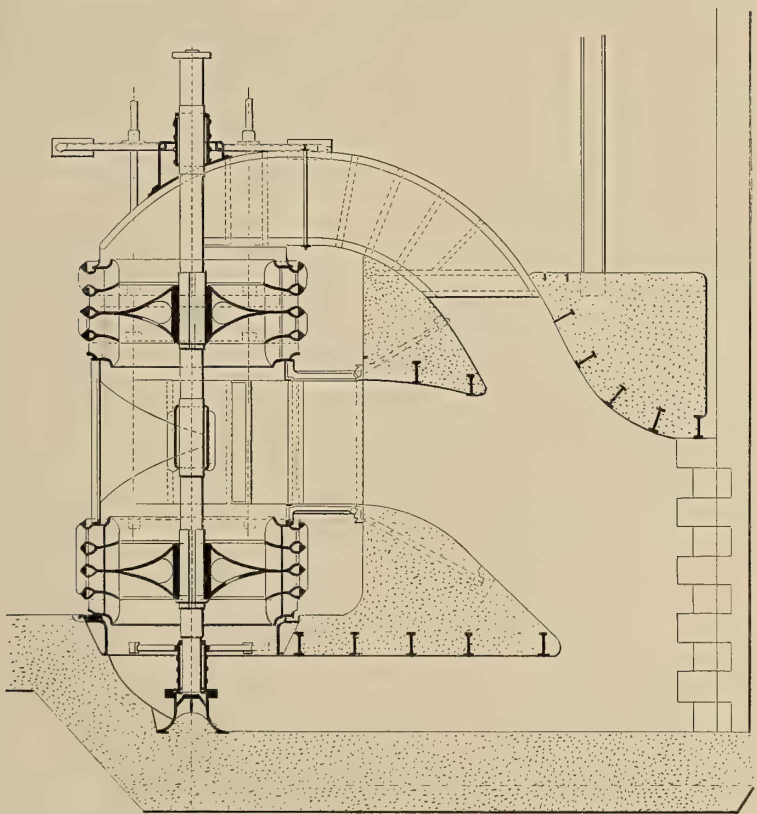
To the right of the turbines is a sluiceway, 6 metres wide, for running off ice which may collect about the screens in front of the turbines, and for emptying the canal of water and also of mud and other waste matter which may be carried down in the central gutter. Alongside of this waste gate is a lock for small boats. The tail-race was blasted out of the solid rock. The stretch of Swiss bank opposite the mouth of this race is artificially protected against damage from the outflowing waters.

Each of the twenty turbines is in a chamber 5.5 metres wide and 10 metres long in the clear, and the chambers are separated from one another by walls 1.25 metres thick. Each chamber can be protected against an excessive pressure of water in the upper canal by a pair of gates, made of rolled iron plates, which

turn on vertical axes. As these are not sufficiently water tight when it becomes necessary to have the turbine chamber entirely dry for repairs, bulkheads are provided for above and below the turbine house. In order to get rid of any remaining water, each chamber has a suction pipe which can be connected with portable, electric, centrifugal pumps. Ten of the chambers can be shut off from the water in the tail-race by wrought iron gates which are raised and lowered by movable cranes in the dynamo house; the remainder, by means of bulkheads.

The concrete arched ceiling has a minimum thickness of 0.75 metres at the top, and the circular opening therein, through which the different parts of the turbines can be lifted, is 3.5 metres in diameter and surrounded by an iron rim. For moving and erecting heavy pieces in the dynamo house electric cranes are provided. To afford protection against floating objects there is a grating which extends the whole length of the turbine house, and whose bars enter the water at an angle of 45 degrees.

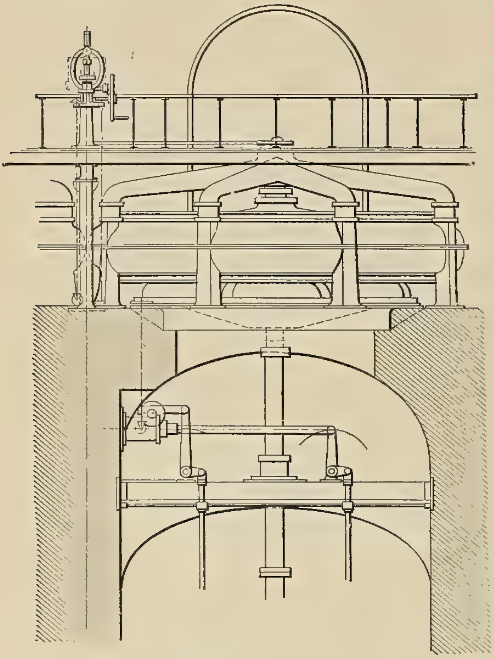
The dynamo building extends over all the turbine chambers, the boat lock and the sluiceway. It has a clear width of 10 metres and is 150 metres long. At both ends there are workshops and storerooms for reserve parts. The total height of the building from foundation to the ridge of the roof is 24 metres, while the clear height of the generator room is 8 metres. Roadways and tracks run from the dynamo building up to the



A SECTION THROUGH ONE OF THE TURBINES.

streets on the Baden bank, and a bridge which it is proposed to build, will connect the two banks of the river.

According to the original plan the water wheels were to have been Jonval turbines. But as the head varies at different times from 2.5 to 5 metres, the turbines must be able to operate with correspondingly varying quantities of water, and for this and other reasons, after the minimum speed of the dynamos had been fixed at fifty-five revolutions per minute, it was decided to use Francis reaction turbines. As the



A PARTIAL WHEEL PIT SECTION WITH DYNAMO IN POSITION.

wheels and the dynamos are directly coupled, an upper bearing was necessary, where friction was reduced to a minimum by lubricating with oil under pressure. By this means, and also by doing away with the originally projected gear wheels and by an improved method of conducting the water through the upper canal, a gain of about 2000 effective horse-power was secured.

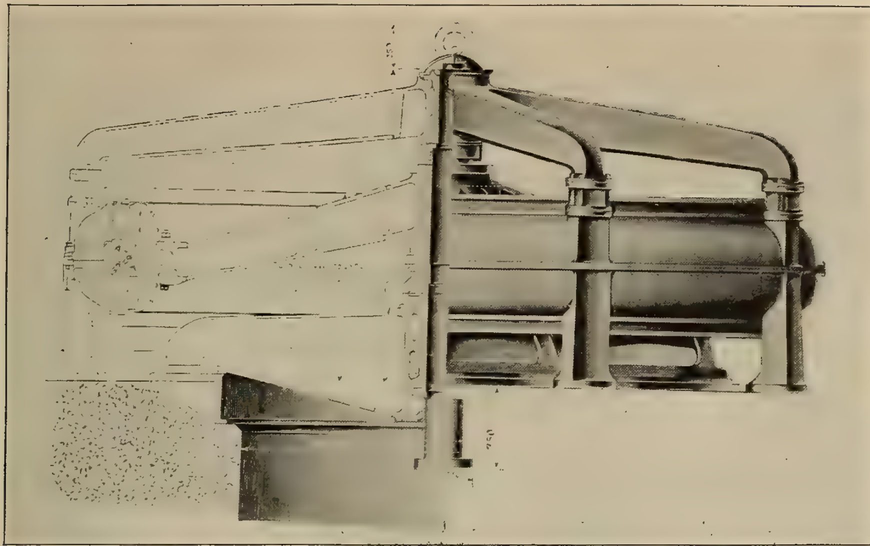
In order to make the most of the varying heads and quantities of water, the present turbines consist of two practically independent wheels, 2.35 metres in diameter, 1.24 metres in depth, and 3.37 metres apart. The wheels are divided into four stories, each of which has thirty-two buckets and thirty-six guide blades. Two stories in each wheel discharge their water upwards and two downwards.

The lower guide wheel rests on a ring which is cast in concrete and leads off the water from the two lowest stories of the turbine to the tail-race. Above the upper guide wheel is a wrought iron chamber which receives the outflowing water from the upper half of the lower wheel and the lower half of the upper wheel, and delivers it to the tail-race. A wrought iron elbow takes the water from the upper part of the upper wheel.

The steel shaft, 300 m. m. in diameter, has three bearings. The lowest one, on the bottom of the turbine chamber, forms only a provisional support for all the parts of the turbine during erection. The bearings are of lignum vitæ, which, on account of its hardness and the amount of rosin it contains, is peculiarly adapted for such service. The turbines and dynamos are coupled together by a connecting shaft, which runs in a substantial bearing. This rests on wrought iron supports, which are also made to serve as a gallery from which the bearings and governing apparatus can be attended to, and which are approached by an iron stairway.

Both upper and lower wheels are governed by gates which may be operated either by hand or by automatic mechanism. The lower wheel must run full of water whatever the head may be. With large heads the upper wheel is closed entirely, as the four stories of the lower wheel are ample. When the head grows less and the volume of water increases, the two lower stories of the upper wheel are opened, and with a still further decrease in the head the two highest stories are also opened.

The electric problem to be solved was how to transmit relatively large amounts of energy to considerable distances with small loss, and distribute them by means of a well designed and economical conducting network. Besides this, the



SECTION AND ELEVATION OF ONE OF THE VERTICAL GENERATORS.

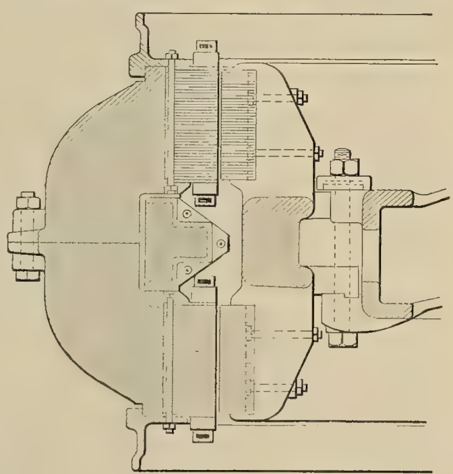
complete independence of the different centres of consumption had to be secured, and a system chosen which would allow an advantageous use of the electric current for lighting, heating, electrolytic operations and particularly for power.

The polyphase alternating current system of transmission was eventually adopted, with a prospective voltage of 16,500. But as the demand for electrical energy in the near future will be hardly a third of the capacity of the plant, it seemed advisable at first to operate at a potential of only 6800 volts, and afterwards, as the consumption increases, to raise the potential to the theoretically most efficient point.

The design chosen for the generators was one with stationary armatures and rotating pole pieces. The machines consist essentially of two stationary armature rings, mechanically and magnetically connected together by the enclosing frame. These rings are built up of laminated plates, stamped out of sheet iron, and have projecting teeth carrying the coils. These have mica insulation and are slipped on after being wound.

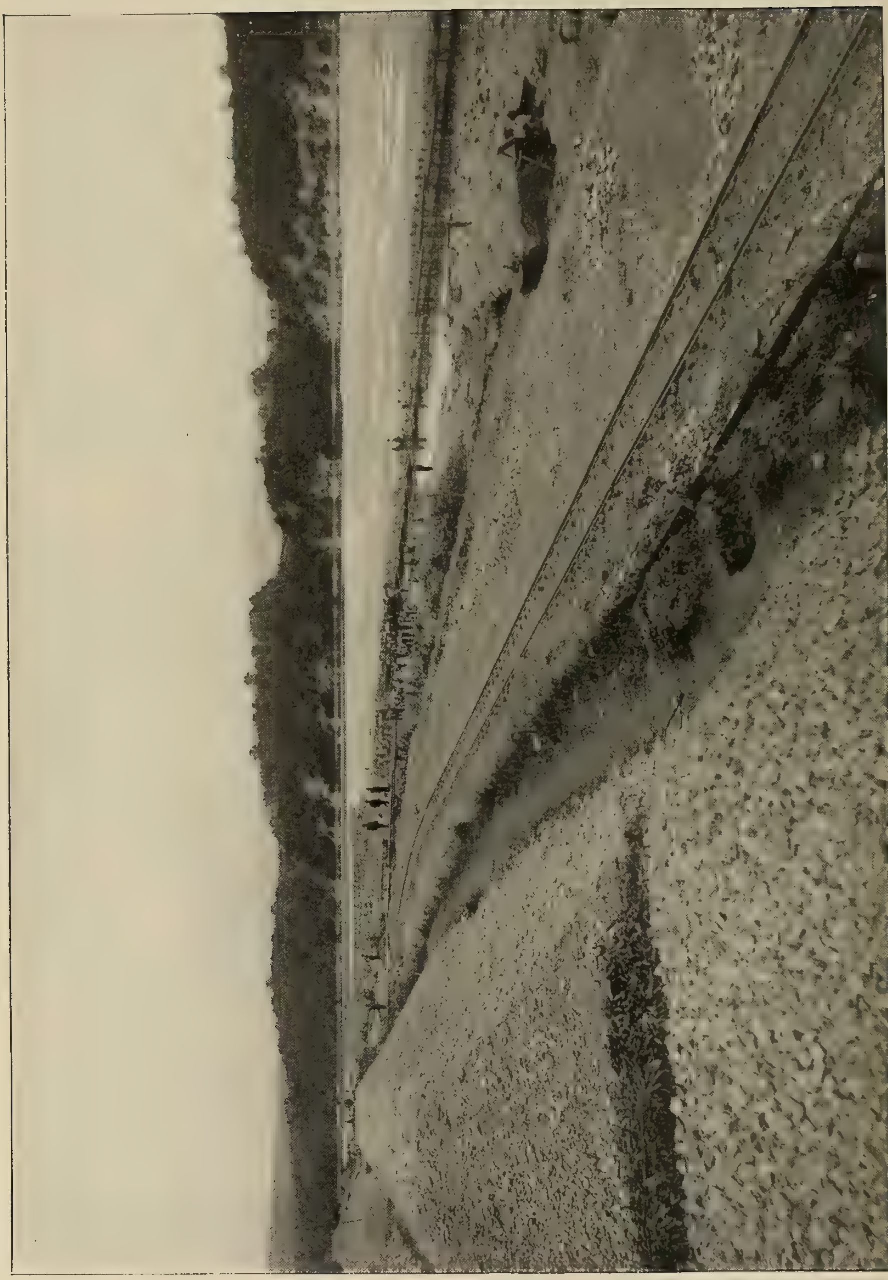
The inductor ring, which is made in five sections, fastened together, and connected with the shaft by a spider, carries, on its outer circumference, fifty-five yoke-shaped pole pieces.

The ring-shaped framework of the dynamo has a diameter of nearly 7 metres and consists of four segments



A GENERATOR DETAIL.

which stand on such high legs on an arch above the turbines that the bearing under the inductor ring is accessible even during operation. The framework



ANOTHER CONSTRUCTION VIEW.

is also divided horizontally into halves which are bolted together on their outer circumference. The design also is such that the inductor ring can be lifted out in an axial direction for changes and repairs.

The bearing in the lower spider of the machine has to carry the weight of the shaft, the turbine wheel and the inductor ring, in short, of all the running parts. To diminish friction loss oil is led to the bearing under a pressure which balances the load. The oil which flows inward in fine streams serves to lubricate the bearing, while that flowing outward is caught in a ring-shaped drip pan.

In order to prevent a scattering of the lines of force, which try to pass from the shaft through the spiders into the frame, the latter is magnetically insulated from the upper spider by a layer of bronze, and the lower spider is insulated by fastening the feet on which the frame rests outside of the bed plate on the cement floor.

Four generators will be used for lighting and fourteen for power; half of the latter will supply chemical industries. In case of an extraordinary increase in the consumption which cannot be taken care of by the two reserve dynamos, the lighting and power plants can be united. This may be effected the more easily as, in general, the demand for power will probably have passed its maximum by the time the demand for light will reach any considerable figure.

The necessary measuring, switching and regulating apparatus is mounted on a marble switchboard which is placed in a gallery running the length of the machine room. The primary transformers, which may, in the future, be required to raise the potential to 16,500 volts, will be placed in a special apartment. Each circuit is provided with an ampère meter, a watt meter and a three-pole high tension switch; the last, in connection with a phase indicator, serves to switch the generators in and out. The potential is measured by means of a small alternating current transformer.

Three rotary transformers, of 150 horse-power each, will furnish continuous current for exciting the generators, lighting the dynamo house and the territory near by and charging a small secondary battery, which will be used particularly for supplying light while the machinery is stopped over Sunday. The principal points of consumption in the secondary network are connected with the volt meter at the station, and the average potential is thus indicated and kept constant by regulating the exciting current.

Independent distributing circuits will supply the lighting transformers and those for power, which are placed as nearly as possible at the centres of consumption. By this means steady light is secured, as well as a simple regulation of the plant. Small motors will be placed judiciously on the secondary lighting network, whose potential is 120 volts, as there is no fear of fluctuations in the lighting service from these.

The secondary network for distributing power will have a potential of 500 volts, as this is adapted to average motors and does not require special safeguards against accidental shocks. For supplying larger towns with underground conductors a double transformation will be resorted to. The secondary network will have a potential of about 2000 volts, while in the tertiary network the usual voltage of 120 will be employed.

The primary conductors of bare copper will be carried overhead on poles 11 metres high and 40 metres apart. These will have iron cross pieces with triple petticoated insulators, whose size has been fixed with regard to the future working potential of 16,500 volts. On the same poles will be the wires leading from the principal centres of consumption to the measuring apparatus and telephones at the central station. There will be lightning arresters on the line at distances of about 500 metres and also where the conductors enter the central station.

Where the high-tension conductors pass over roads, railways and other frequented spots, guards, formed of a network of light wires, will be placed underneath them. The primary conductors

will run only on those sides of the main roads which will be free from telephone and telegraph lines, and along the water courses and railways.

It has been estimated that the power used for industrial purposes in the future area of distribution would amount to 10,500 horse-power, and that to replace the present gas and oil illumination by electricity would require an additional 6000 or 7000 horse-power. These investigations, together with past experiences, led to the assumption that in consideration of the cheap water power the rates could be made so low that it would be possible for even the small consumer to enjoy the advantages of electric light and power, and that the competition of other methods of illumination would be excluded.

The rates for lighting will begin with 40 pf. per kilowatt-hour, which corresponds to a price of 1.2 pf. per ten candle lamp-hour. Rebates up to 80 per cent. will be granted, and in the exceptional cases where this limit will be reached, a ten candle lamp-hour will cost not quite ¼ pf. The price per kilowatt-hour for power purposes will be 1.6 pf.; besides this, the users will have to pay a ground tax, which will vary from 160 to 52 marks.

In order to secure customers for the current as soon as possible, the Rheinfelden company has directed its attention to the formation of separate corporations, which will take large quantities of current and deliver it at a profit to small consumers within certain districts. In this way the "Elektricitätsgesellschaft für Basel-Land" has sprung into being, and has agreed to take 500 horse-power the first year and afterwards more than 1000 horse-power per annum.

With the availability of electric power, it is expected that the upper Rhine district will become an active manufacturing place, with Rheinfelden as a natural centre. The fruitful neighbourhood of Rheinfelden offers advantages for the settlement and cheap support of a large labouring community. Two railroads make immediate connection with outside markets, the Rhine furnishes water for large amounts of power, and the Black Forest of Baden supplies excellent stone and cheap wood for building purposes.

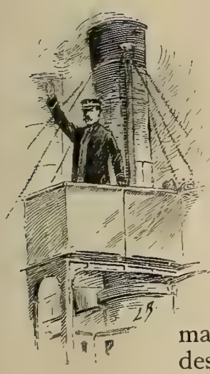
Large tracts of land on the Baden and Swiss banks have been acquired by the power transmission company, and will be given up to manufacturers for building sites. When the Rheinfelden works are completed, a great industrial town may rapidly spring up in the immediate vicinity. Street cars, branch tracks connecting with the main railroad, labourers' houses, water supply and sewers have all been planned.

Two large establishments, branches of the Neuhausen Aluminium Company, and of the electro-chemical works at Bitterfeld, with their staffs of workmen and officials, will form the first colony for the new manufacturing city of the upper Rhine, and other industries will soon join them. The power station, it is expected, will be completed and ready for operation before the end of the present year.

STEAM AND HYDRAULIC STEERING GEARS.

By Edwin H. Whitney, M. E.

"Fortune brings in some boats that are not steer'd."



MODERN steering machinery is so nicely adjusted and balanced that it is quite possible for the steersman to govern the course of the largest ship by the aid of one finger, — and, more than this, ships have been automatically steered on their courses without any attention from the steersman, except to set a dial to the desired course.

Until that genius in valve gear, Frederick E. Sickels, put his attention upon the steering gear of vessels, the helmsman of a ship was as likely to be controlled by the steering wheel as to control it. Sickels' idea, as told in a biographical sketch of the inventor, published about two years ago in *The American Machinist*, is now in use upon almost every steam ship of any magnitude afloat. It embodied the only method by which the object sought could be obtained. The rudder of a ship must follow the wheel, start as the wheel starts under the impulse of the steerman's hands, stop when the wheel stops, and remain immovably fixed until the steering wheel is again moved. This end was gained by Sickels.

A single eccentric will operate equally the valves of two steam cylinders, set at 90 degrees from each other, and two cylinders so set will turn a shaft. Sickels therefore connected the eccentric to operate the valves of a pair of 90-degree cylinders, not to the engine shaft, but to the shaft of the steering wheel; hence, if the power of the engines is enough to move the rudder, the engines make exactly turn for turn with the steering wheel. An important improvement since the time of Sickels' first steam steerer was effected by Mr. Mooney, chief draughtsman at the Morgan Iron Works, New York City, who put a rope driving multiplying gear between the steering wheel shaft and the eccentric carrying shaft and thus made, say three-quarters of a steering wheel turn give the eccentric shaft the say, four turns needed to put the helm hard over, and at the same time limited the number of eccentric turns possible in either direction, and thus stopped the engines whenever the rudder reached either extreme position.

Sickels was certain, from the results of an experimental trip, that steam steering gear must come into universal use, and, full of hope and courage, went to England to introduce it, but met with ill success.

The introduction of steam steering gear on British vessels was due to Mr. McFarlane Gray. There are many modifications of it, but it was to him that the first principle was due and on this subsequent modifications were founded. Mr. Gray designed the steering gear for the *Great Eastern*.

In a warship the steering gear was always a difficulty, as space was cramped owing to the protection required for this vital part of the ship's economy. In large warships the work was always near the rudder, so that no rods or chains were used for the transmission of power as in many of the merchant vessels.

In a paper read before the British Institution of Naval Architects some time ago, Mr. A. Betts Brown, of Edinburgh, enumerated the following requirements of an ideally successful steering gear,

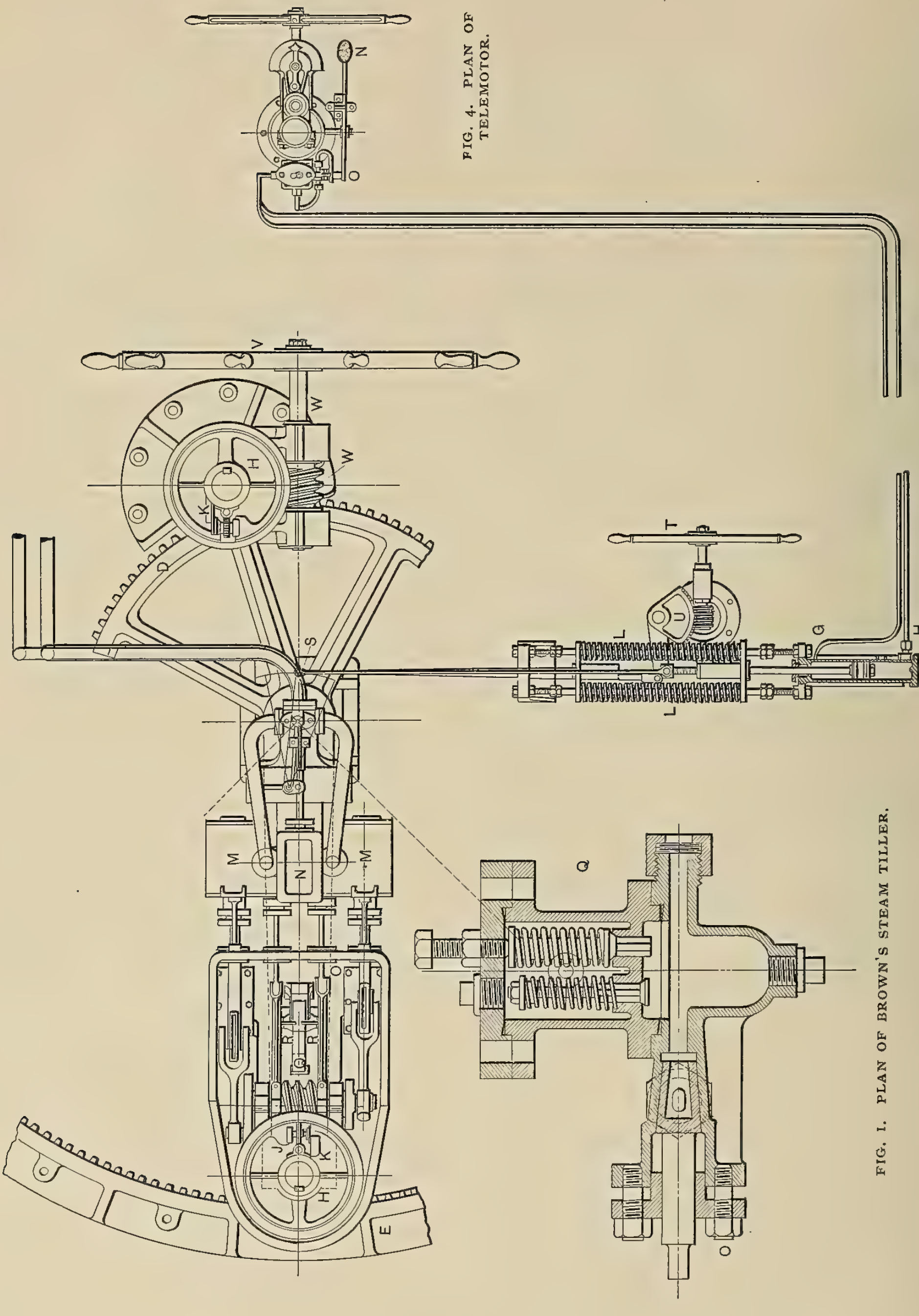


FIG. 4. PLAN OF TELEMOTOR.

FIG. 1. PLAN OF BROWN'S STEAM TILLER.

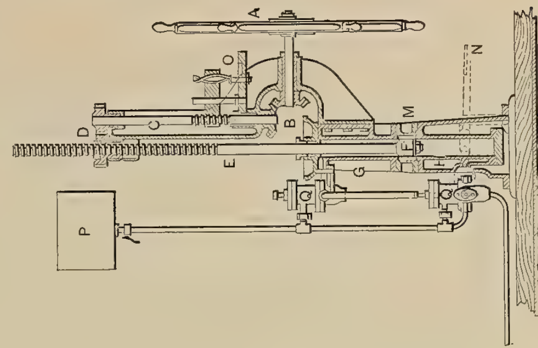


FIG. 3. VERTICAL SECTION OF BROWN'S TELEMOTOR.

whether it be actuated by water or steam:—

First.—The steering engine or machine should be attached to the rudder head without the intervention of chains or ropes.

Second.—It should let go the rudder when unduly strained, and, when the abnormal strain disappears, must return to its former position.

Third.—An easy method should be provided of connecting from steam to hand gear, which shall not involve the engagement of a clutch or the more common practice of shipping large bolts into a fixed crosshead from a loose one, all of which appliances take much valuable time to get into place, particularly when a ship is rolling at sea with the rudder adrift.

Fourth.—The communication to the bridge from the machinery aft should be of a kind which dispenses with rods, chains, and shafting, all being equally troublesome to the shipbuilder to arrange and to the officers attending to them to keep in order.

To meet these wants, Mr. Brown designed what is termed a steam tiller and telemotor, shown in Figs. 1 to 4. References to these and to the several other illustrations in this article will help to form a very good idea of typical modern steering gears. There are a number of others in use, modified in various details, but none more illustrative perhaps, of current practice.

Fig. 2 represents an elevation of Brown's steam tiller with the hand steering gear; Fig. 1 is a plan; Fig. 3 shows the telemotor in vertical section; and Fig. 4 is a plan of this, showing also a section of the corresponding cylinder aft.

In Fig. 2, *A* is a cast steel tiller, keyed on to the rudder head *B*, having at its after end a double jaw, *C*, fitted with bearings. At the other end *D*, Fig. 1, there is a toothed segment, into which a pinion gears. Aft of the tiller there is bolted to the deck a toothed quadrant *E*

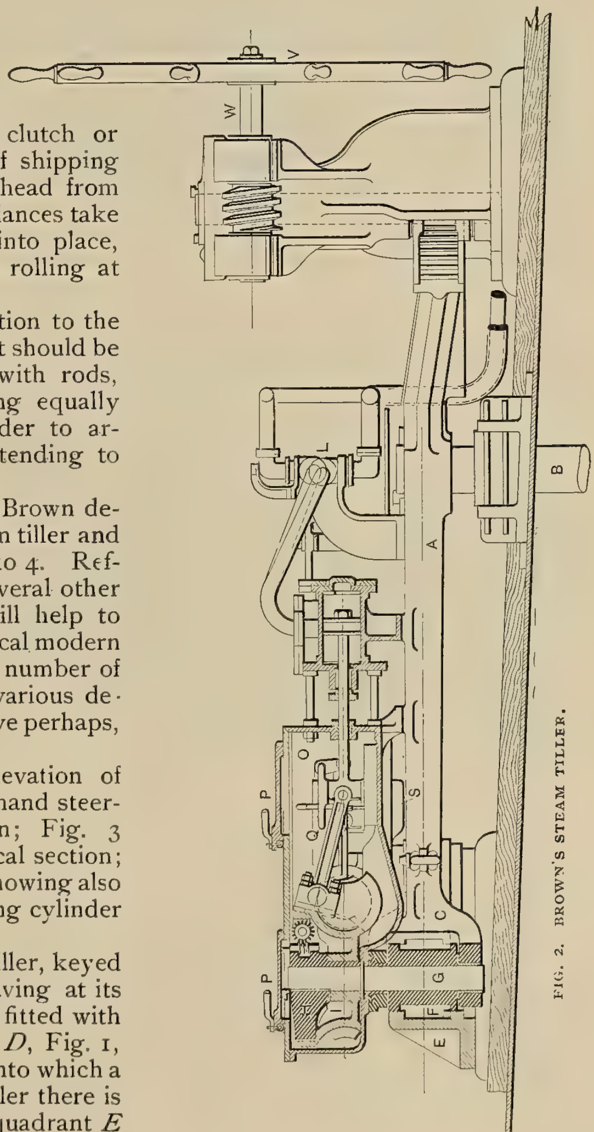


FIG. 2. BROWN'S STEAM TILLER.

with which the steel pinion *F* gears. The shaft *G* is shrunk into this and, passing through the bearings on the jaws of the tiller, terminates in an expanding clutch wheel *H*. The worm wheel *J* embraces this clutch wheel, a strip of elm wood being interposed circumferentially between the two. This wood possesses the property of having a co-efficient of friction nearly constant, whether it is wet or dry. The necessary friction to drive the shaft *G* is effected by the worm and worm wheel arrangement *J* expanding the clutch wheel against the laminated spring *K*.

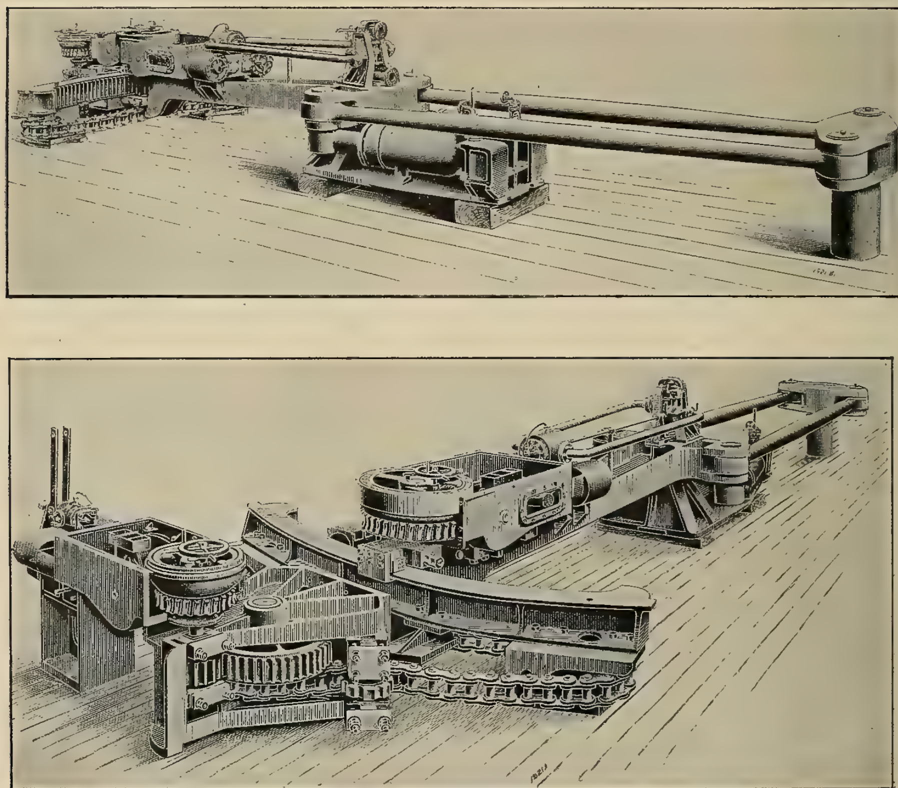


FIG. 5. STEAM TILLER STEERING GEAR USED ON THE CUNARD LINE STEAMERS "CAMPANIA" AND "LUCANIA." BUILT BY MESSRS. BROWN BROS. & CO., EDINBURGH.

The steering engines are carried on the tiller, and move around with it, receiving and exhausting their steam through a double stuffing box arrangement, *L*, mounted on the axis of the rudder head. The steering lever operating on the valve is shown at *S* and is actuated by a hand wheel, *T*, with worm and sector *U* with its shaft and corresponding lever. This opens the slide valve *N* in either direction, and the motion of the tiller and engines, moving round, shuts it again.

The hand-steering wheel is shown at *V*. It is mounted on the worm shaft *W*, which gears into a worm wheel precisely similar to that of the steering engine. A vertical shaft passes down into a steel pinion, which gears with the toothed segment *D*. This shaft is brought into gear with the worm wheel by an expanding clutch similar to that on the engine shaft, and lettered, similarly, *H*.

In proportioning the engine for the torsional strain on the rudder head it is not necessary to consider the question

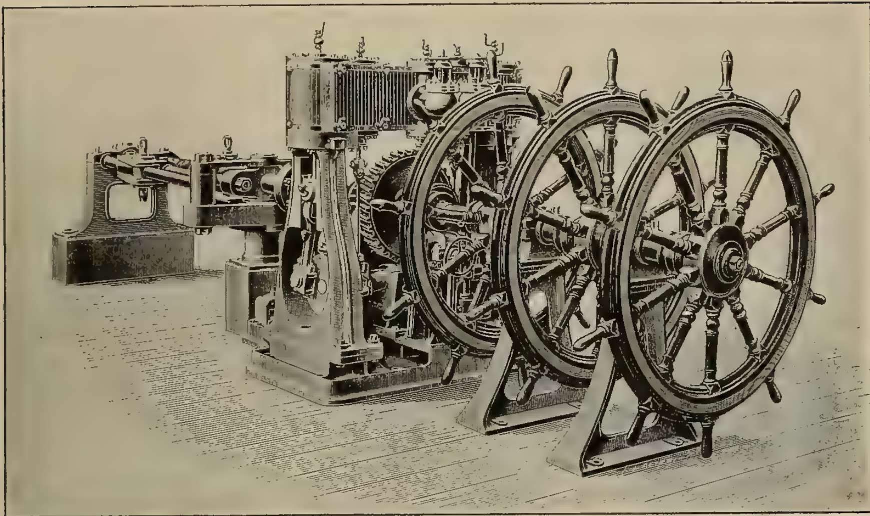


FIG. 6. STEAM STEERING GEAR OF THE BRITISH ROYAL MAIL STEAMER "NILE." BUILT BY MESSRS. NAPIER BROS., LTD., GLASGOW.

of a safe strain,—in fact, the engines may be made overpowerful so as to allow for reduced boiler pressure. In practice, the clutch *H* is expanded sufficiently tight at full speed trials to put the helm hard over, but no more, and the worm wheel screw is then set to that, so that in changing from hand to steam it cannot be set up dangerously tight.

It will be seen from this arrangement that any abnormal strain on any part of the gear or rudder head, caused by heavy seas, must be transmitted through the elm wood liner, held tight by the spring *K*, which has not sufficient hold to break any part of the machinery, but slips, and the valve gear, opening, brings the rudder into its original position. This friction clutch arrangement being also on the hand steering gear, admits of connection at any position of the rudder.

The object of the telemotor is to communicate the motion of a revolving wheel at the bridge to the rectilinear motion of a piston and its connecting rod, attached to the steering lever and acting upon a steering valve which may be either steam or hydraulic.

Fig. 3 shows a vertical section of what is really a hand pump. The steering wheel *A* drives a shaft and a pair of bevel wheels, *B*, which actuate a vertical shaft, *C*, so arranged that it can be carried up to the bridge. The pinions *D*, one of which forms a nut, act on the screwed piston rod *E*. This is shown at midgear, the piston *F* being in a cylindrical distance piece forming part of the upper cylinder *G* and the lower cylinder *H*. This distance piece, however, allows a free passage of water through an annular port, from the cylinder *G* to the cylinder *H*, being open one-sixteenth inch at the top and bottom of these cylinders. On turning the wheel *A*, the piston *F* will travel one-sixteenth inch each way before the cylinders *G* or *H* become effective hand pumps.

Referring to the lower part of Fig. 1, close to the steering gear there is an ordinary double-acting hydraulic cylinder, fitted with a piston and its rod which is connected to a crosshead, and from there to the lever *S* in the steering gear. The cylinder *G* on the bridge is connected by a one-half-inch pipe to the corresponding part *G* on the cylinder aft, while the cylinder *H* is connected to the corresponding part *H* aft. The pipes and cylinders being full of water, it will be seen that as the piston *F* passes the distance piece, say, on the upper stroke, the piston aft will move to-

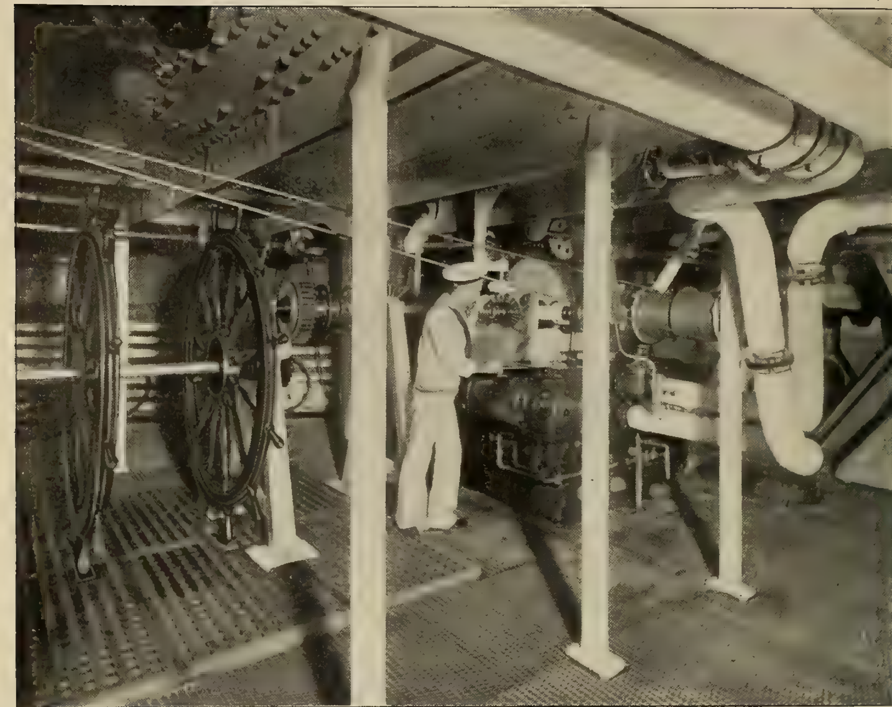


FIG. 7. THE STEERING GEAR ON THE U. S. BATTLESHIP "MASSACHUSETTS."

ward the cylinder end. Without entering into a more minute description of the telemotor, it may be said that automatic regulation is provided for and any external leakage is made up by water stored in a tank, *P*, and safety valves are fitted to allow for the expansion of the water.

The steering gear on the steamers *Campania* and *Lucania*, of the Cunard Line, was provided by Messrs. Brown Bros. & Co., of Edinburgh, and is of the type that has just been described. The arrangement, however, has been somewhat modified to suit the limited space available. (See Fig. 5.)

Owing to the fineness of the after part of the ships, connecting rods, about 20 feet long, were fitted from the rudder crosshead to the steam tiller, which is of cast steel, about 17 feet long, and acts upon a 4-foot crosshead. No hand steering wheels are provided, but auxiliary steam steering gear is fitted forward of the main steam tiller, and takes hold of the end of the tiller.

To guard against the possibility of an accident to these steering gears, a pair of powerful hydraulic cylinders are provided, the rams of which take hold of the connecting rod pins at the steam tiller end. Water circulates between these cylinders, passing through a communicating valve, so that the attendant can at once shut the valve and arrest the motion of the rudder.

The valve gears on the main and auxiliary steering engines are operated by a hydraulic telemotor cylinder, connected by two lines of one-half-inch copper pipe to the bridge, where the telemotor is placed. In addition to this steering station there is also one on the poop, which communicates, by means of a vertical shaft, with the valve gear. There is also an under water steering station from which the vessel can be steered with the aid of telegraphic instruction from the bridge.

Some idea of the strength and solidity of the construction, as illustrated by Figs. 4 and 5, may be gained from the

fact that the machinery weighs 45 tons, the bulk of it being of forged and cast steel. The rudder is of large area, 12 feet broad and 20 feet deep, and with the twin engines working in opposite directions will turn the vessel in her own length.

On the British cruiser *Theseus* the steering engine is placed aft, below the protective deck, and arrangements have been made for alternate methods of working the rudder. The gear can be changed from steam to hand gear in the usual way, but should the main steering screw of the gear become damaged, the connecting rods of the crosshead on the rudder can be disconnected and attached to tackles provided for the purpose. These can be worked by the hand wheels or by the steering engine, the falls being led over a barrel. Should the engine be disabled or the hand wheel break down, the rudder can be worked by the tackles direct, eye bolts for luff tackles being placed in the bulkheads. In all, there are five distinct methods of steering, so that as long as the rudder itself holds good, there are four alternatives if the main gearing should get out of order.

The steam gear will put the rudder from hard-a-port to hard-a-starboard in thirty seconds, with the ship going at full speed. There is the usual helm indicator on the mast. This consists of a continuous wire rope, which winds over a barrel attached to the steering gear. Half way up the mast, attached to the rope, is a flag on one side, and on the other there is a cone. As these ascend or descend, other vessels are able to tell whether the vessel's helm is port or starboard.

Fig. 6 shows the steam steering gear of the Royal British Mail steamers *Nile* and *Danube*, constructed by Napier Bros., Limited, of Glasgow. This is arranged to work direct with a double-threaded screw or, if expediency demands, it may be worked with chain and barrel, operated by quadrant. The change is easily and quickly made and either of the arrangements can be worked by steam or hand.

By a simple arrangement of clutches, the mechanism is shifted from screw to

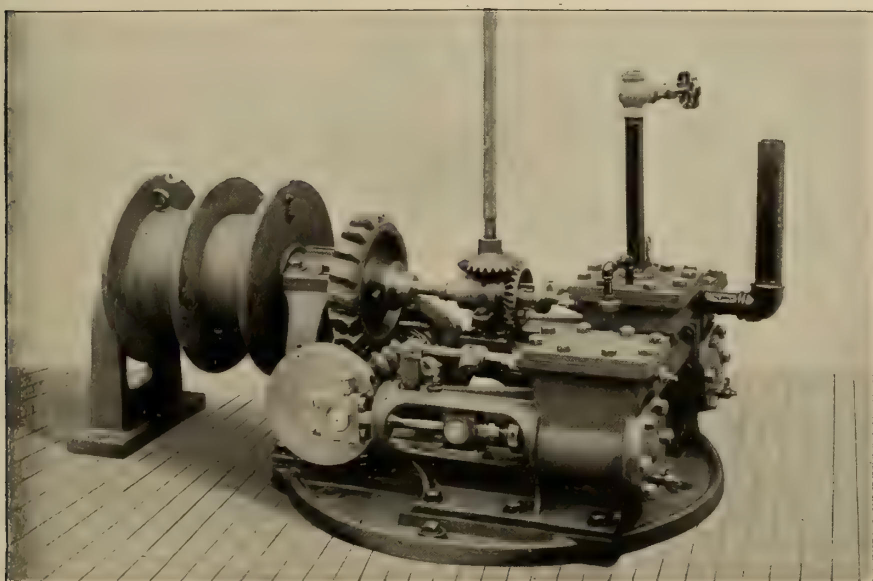
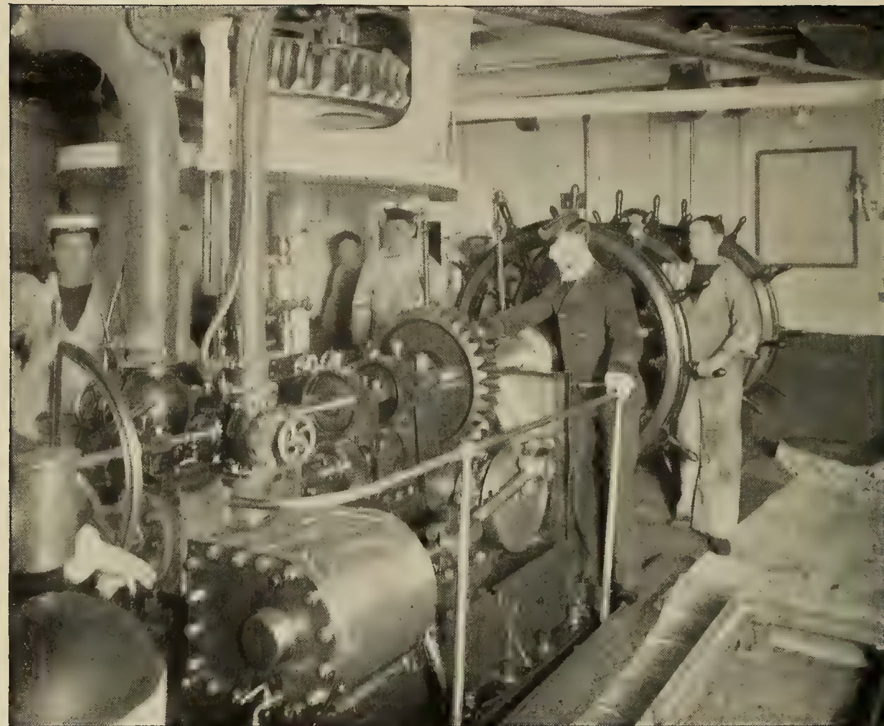


FIG. 8. STEAM STEERING MACHINE MADE BY THE MARINE MACHINE AND CONVEYOR CO., NEW YORK CITY.



FROM A PHOTO BY W GREGORY & CO., LONDON

FIG. 9. THE STEERING ENGINES ON H. M. S. "RESOLUTION."

chain barrel gear or disconnected from steam to work by hand. The cylinders are 10 inches in diameter by 10 inches stroke, and work at a steam pressure of 160 pounds to the square inch. Everything is made to stand heavy strains, all working parts being of steel, and the wheels being machine cut. The operating of the valves of the steering engine from the bridge is done by a telemotor system.

The steering gear of the South African steamer *Norman*, of the Union Line, as well as to the four other steamers *Gaul*, *Goth*, *Guelph*, and *Greek*, of the same company, is of the Wilson and Pirrie type, constructed by Harland & Wolff, Limited, of Belfast. Illustrations of it are given in Figs. 10 and 11. The engines are of the vertical high-pressure type, with piston valves. The diameter of the cylinders is 9 inches, and the stroke 10 inches. On the shaft is a worm, geared to a manganese bronze wheel working in a horizontal plane on a vertical shaft, on which also there is a spur pinion working on the manganese bronze teeth of the quadrant fitted, as shown, to the rudder head.

The strong spiral springs, shown in the plan, are for taking up any shock conveyed from the rudder to the quadrant. These springs are fitted up under compression in such a manner that whether the rudder is forced to port or starboard, the springs are still further compressed, so that both are available for resisting the strain in the rudder. Neither is idle, no matter in which way the strain may come.

The engine is operated by shafting from the main bridge, or from the poop, on which it is placed, in a deck house. It can be readily thrown out of gear, whereupon the hand steering gear works direct on the rudder head. The turning of the wheels conveys, through gearing, rotary motion to a shaft with a right and left handed screw, on which are two nuts, working forward and aft, and

connected by rods to the rudder head.

The steering gear on the American Line steamer *St. Louis* was constructed by Messrs. Williamson Bros., of Philadelphia. In this there is a right and left-handed screw, 8 inches in diameter and 10 feet long, on which run two nuts, from which connecting rods go to the crosshead on the rudder. The nuts are made in halves, so that, should it be necessary, they may be quickly removed. The revolving of the screw operates these nuts, and, through the nuts, the rudder.

The engine used is horizontal, with two cylinders, 14 inches in diameter by 12 inches stroke. The piston valve is operated direct by a hydraulic telemotor, or by shafting from the deck above, through bell crank levers. The crank shaft of the engine works brass gearing with double helical teeth, made in halves to admit of machine cutting, and thoroughly pinned together.

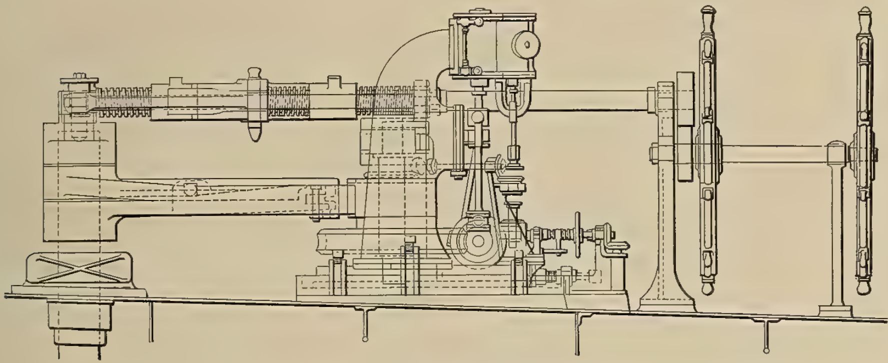


FIG. 10. WILSON & PIRRIE'S STEAM STEERING GEAR. CONSTRUCTED BY MESSRS. HARLAND & WOLFF, LTD., BELFAST.

Buffer springs are used to arrest the motion when the rudder is put hard over, and when released they aid in bringing it back to amidships. Clutches throw the engine out of or into gear, and similarly three hand wheels may, when required, be geared up to the right and left-handed screw. There is, further, a

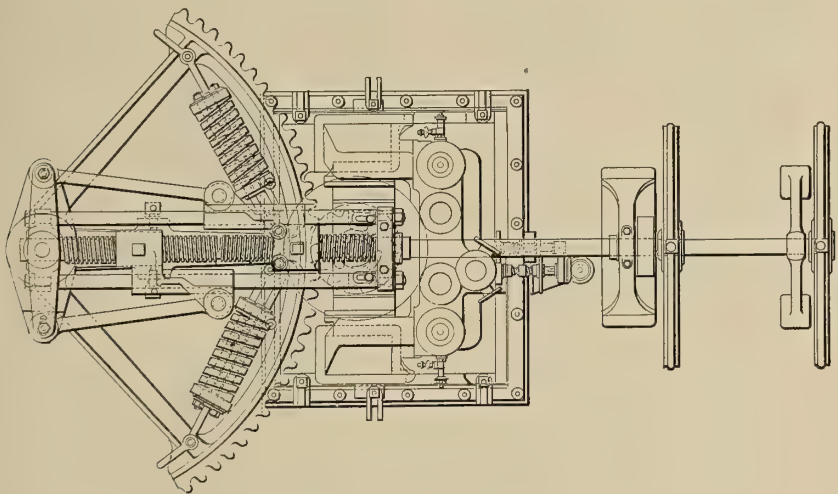


FIG. 11. PLAN OF WILSON & PIRRIE'S STEERING GEAR.

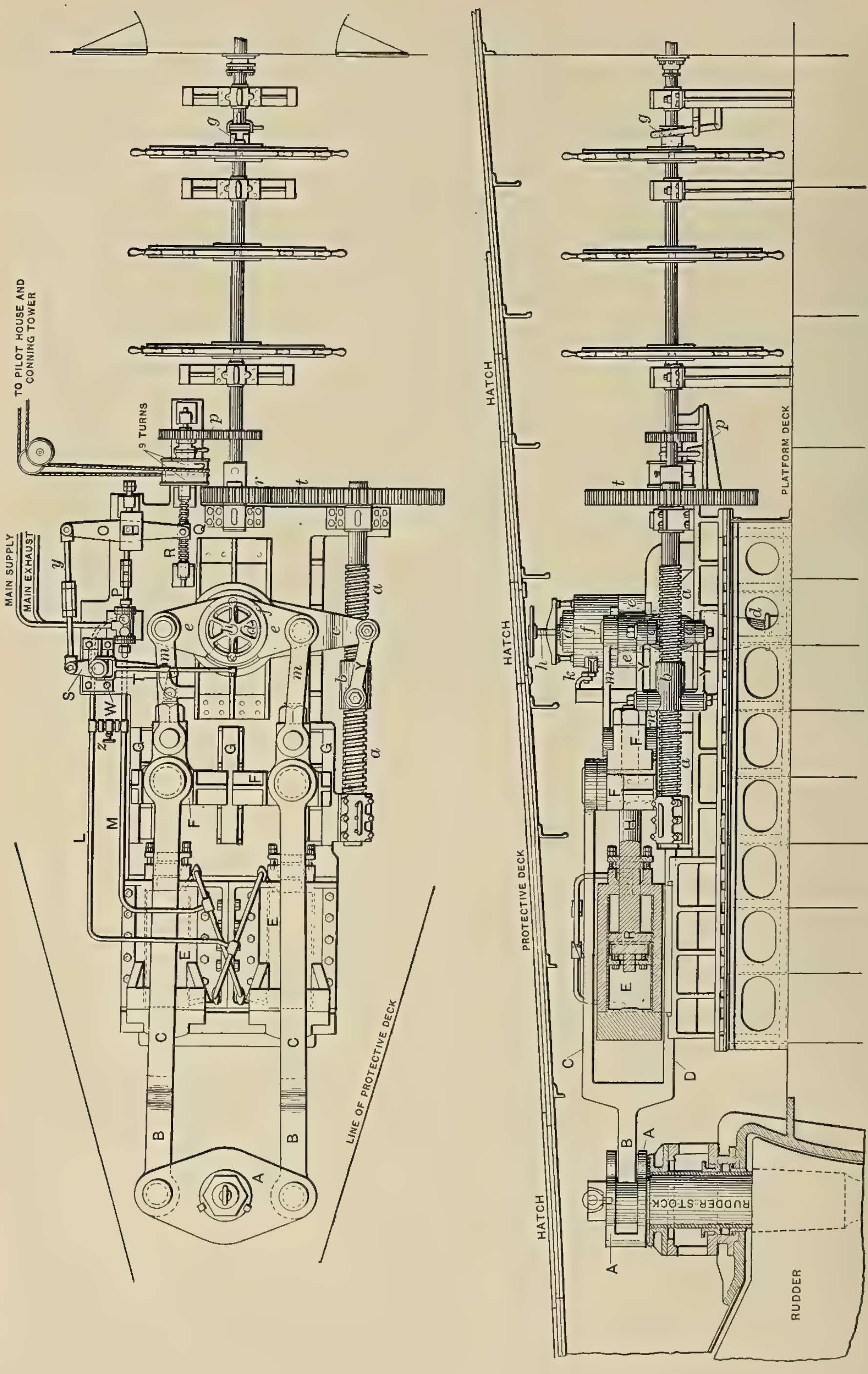


FIG. 12. THE HYDRAULIC STEERING GEAR OF THE U. S. CRUISER "OLYMPIA," CONSTRUCTED BY THE UNION IRON WORKS, SAN FRANCISCO, CAL.

tiller on the rudder head, standing out above the right and left handed screw. By means of this the ship may be steered either by the interposition of the steam engine or hand gear, through wire ropes winding around a series of pulleys, and made fast to the end of the tiller. A friction strap is provided to a horizontal pulley on the rudder head to take up the strain of the rudder while any change in the gearing is being made.

Of the hydraulic steering gears used on some of the ships of the United States Navy, the cruiser *Olympia* and the battle ship *Oregon*, for example, United States Naval Constructor Albert W. Stahl some time ago gave an account in the shape of a paper read before the American Society of Naval Architects and Marine Engineers. The gears on both the above ships are nearly identical.

Fig. 12 shows the general arrangement of the hydraulic gear in the tiller room. To the top of the rudder stock is secured a heavy cross yoke, *A*, at right angles to the plane of the rudder. To each end of this yoke is attached a connecting rod, *B*, having two branches *C* and *D*, passing above and below the hydraulic cylinders *E*, respectively, and having their forward ends attached to the blocks *F*. These move in fore-and-aft guides *G* and form the crossheads to which the forward ends of the piston rods *H* are attached, the after ends of the latter being secured to the pistons in the hydraulic cylinders.

This is all there is of the main gear, the remaining portions of the complete apparatus consisting of valve gear for controlling the distribution of the water and of emergency arrangements for steering by hand. The forward end of each cylinder is connected by a pipe with the after end of the other cylinder, each of these pipes being directly connected, without any intervening valves, with one of the two pipes *L* and *M*, leading to the valve chamber of differential controlling gear. These pipes operate as supply and exhaust pipes alternately, according to the direction of motion of the rudder.

The function of the differential valve gear relates to the distribution of the water. Both ends of each main cylinder being full of water, the pipe leading to the after end of the starboard, and the forward end of the port cylinders, is caused, by the differential gear, to be connected with the full hydraulic pressure, while, by the same action, the pipe leading from the other ends of the cylinders is connected with the exhaust or drain. The result is a motion of the rudder to starboard; the converse action of the differential gear sends the rudder to port. The diameter of the cylinders, supposing the length of the rudder yoke to be fixed, is determined by the area and shape of the rudder, the maximum speed of the ship, and the maximum angle of helm.

The differential controlling gear is shown in the general plan, opposite, and separately, on a larger scale, in Fig. 14. The controlling and distributing valve in this gear consists of a small slide valve *N*, moving across two circular ports. The ports in fact, are simply two holes, drilled in the bottom of the cylindrical valve chamber, and extending up through the flat valve seat. The pipes *L* and *M*, mentioned above as leading from the cylinders to the valve chamber, are screwed into the lower ends of these ports.

The main supply pipe from the pumps enters the valve chamber on the side, above the valve, while the exhaust, or drain pipe, leading back to the supply tank, leaves the valve chamber by an opening in the centre of the valve seat, under the valve. The latter is caused to move by the action of a lever *O*, pivoted near its centre to the valve stem *P*. The inboard end of this lever is provided with a nut *Q*, which works on the screw *R*. The revolution of this screw is accomplished in various ways, according to the point from which the ship is being steered.

If the steering is done from the pilot house or conning tower, the screw is revolved by means of a drum, *J*, securely fastened to the screw shaft and having wound about it, in many turns, a small wire rope, which leads upward and forward over sheaves, and is finally similarly wound round a vertical barrel

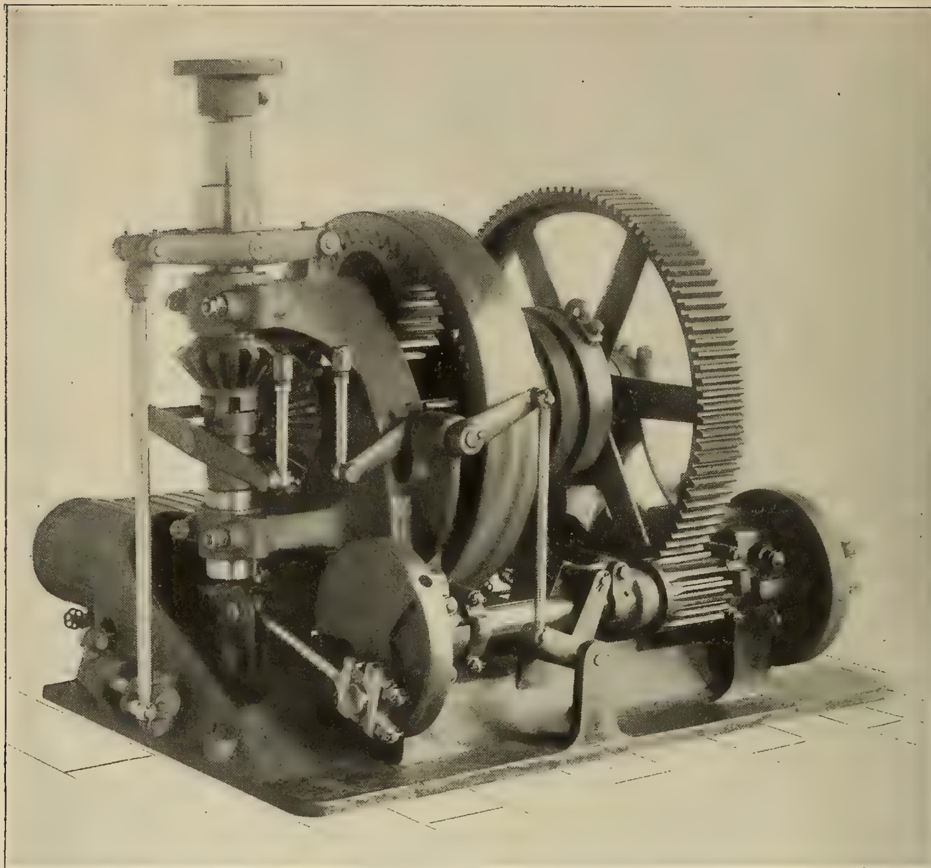


FIG. 13. STEAM STEERING ENGINE BUILT BY THE GLOBE IRON WORKS CO., CLEVELAND, OHIO.

located under the protective deck and connected with the wheels on deck; or the screw may be revolved by a pinion on its shaft, gearing with another pinion on the wheel shaft. Either of these methods of driving the screw can be thrown into or out of use by the clutch *p*.

The screw shaft being revolved, the nut *Q* on the end of the lever *O* is moved forward or aft as the case may be, and the middle portion of the lever, and consequently the valve stem and the controlling valve, partake of the same motion in a less degree. The water being thus turned into one of the pipes *L* or *M*, and the other of these pipes being connected with the drain or exhaust, the pistons in the main hydraulic cylinders are caused to move, carrying with them the connecting rods, the rudder yoke and the rudder.

Having thus started the rudder in the required direction, it now remains to stop it when the desired angle of helm is reached. This is accomplished by imparting to the outboard end of the lever *O* a motion opposite in direction, and so proportioned in amount to that originally imparted to its inboard end, as to bring the controlling valve back to its original middle position and thus close off both pipes. The detailed method of imparting this second motion is evident from the illustrations.

The outboard end of the lever *O* is connected by the rod *V* to the arm *S*. A second arm, *T*, is connected by a link to the end of one of the main hydraulic piston rods. When these two

arms, whose centres of motion are vertically over each other, are connected and caused to move together by the clutch *W* (as they always are when the hydraulic gear is in use), the motion of the rudder, acting through this piston rod, causes a sufficient movement in the outboard end of the lever *O* to close the ports of the distributing valve, and thus stops the action of the mechanism. While this compound action of starting and stopping just described really consists of two separate and distinct operations, yet the closing of the valve follows rapidly after its opening, so that the practical effect of the whole arrangement is that the rudder closely follows the motion of the steering wheel.

The *Olympia* can be steered by hand from the wheels under the after bridge or from the wheels in the tiller room, the shafting of these two sets of wheels being connected at will by the clutch *g*. The shaft of the lower steering wheels drives the hand gear direct by means of the two gear wheels *r* and *t*.

The revolution of the steering wheel shaft thus causes the revolution of the heavy screw *a*. On this screw works a nut, *b*, secured by the link *Y* to one end of the arm *c*, the other end of the latter being firmly secured to the vertical spindle *d*. Revolution of the steering wheel shaft thus imparts to this spindle a slow motion about its vertical axis.

Just above the arm *c*, and revolving freely on the spindle *d*, is the yoke *e*, the ends of which are connected by links *m* and *n* to the blocks carrying the ends of the respective main hydraulic piston and connecting rods. This yoke thus partakes, at all times, of the motion of these rods, and, in fact, always keeps parallel to the main yoke *A*.

At the upper end of the spindle *d*, and connected to it by two vertical keys, so that it may slide up and down freely, but cannot revolve, except with the

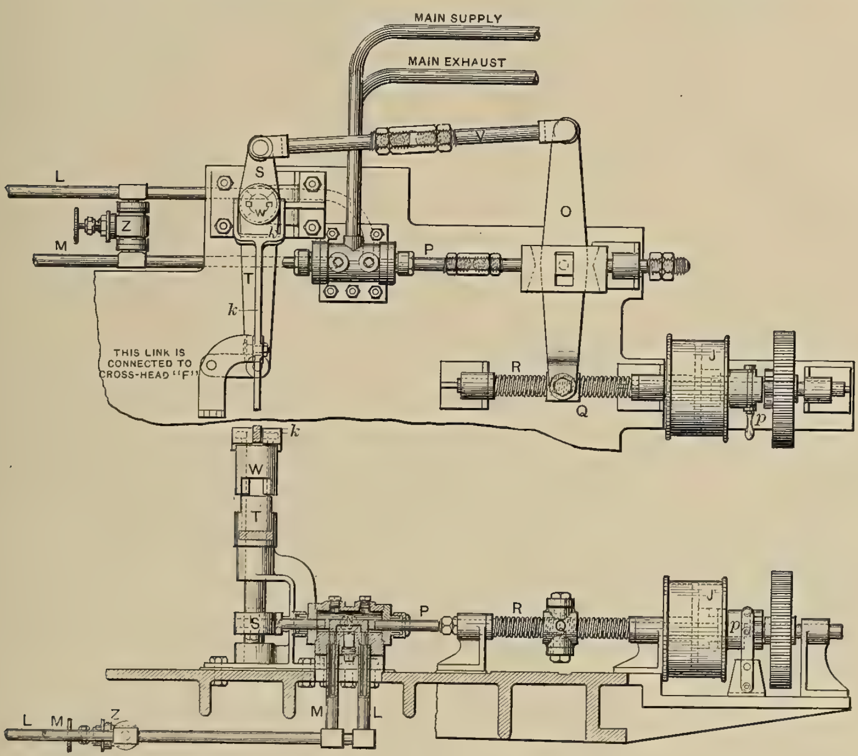


FIG. 14. THE CONTROLLING GEAR OF THE U. S. CRUISER "OLYMPIA'S" STEERING MACHINERY.

spindle, is the clutch *f*. This clutch, when down, locks with the yoke *e*, and thus transmits the motion of the spindle, through this yoke and its links, to the main connecting rods and thence to the rudder.

The clutch is moved up or down, as desired, by means of the screw *h*; and the vertical movement of the clutch is transmitted by the lever *k* to the smaller clutch *W*, thus closing off the hydraulic gear when the hand gear is in use, and *vice versa*. A by-pass valve, *Z*, is fitted to permit the water to circulate between the two ends of each cylinder when the hand gear is in use.

The subject of the electrically driven steering gear has not been treated in this article because this branch has not passed the experimental stage. As mentioned in the opening paragraph, ships have been automatically kept on their course. This has been accomplished by means of the electro-magnet and electro-motor.

One of the best methods of controlling the steering gear aft from the bridge is by the electric current, and this application has been very successfully made, so that there seems to be no reason why the electric steering gear may not be expected to succeed the steam and the hydraulic apparatus.

THE LARGE GAS ENGINE.

By E. F. Lloyd.

A partial reprint of a paper read before the Ohio Gas Light Association.

THE present development in gas engine design is divided sharply into two general classes, single-acting and double-acting. The former is much older and still much more in use; the latter is a comparatively recent development, and has aimed more to occupy the field of higher powers than has its single-acting competitor.

Of the single-acting engine there have been a number of types, of which it is sufficient to say that the only one which has survived to attain a widespread reputation is the Otto.

In double-acting engines the original practicable type was known as the Griffin, or 6-stroke cycle, which introduced an idle revolution for the purpose of cleansing the cylinder from the products of combustion which remain in the compression chamber of the Otto cycle. This scavenging revolution, however, was abandoned, and the Otto cycle substituted; but the double action, in general design the same as the ordinary horizontal steam engine, was retained, and this feature constitutes the essential difference between the two types.

It is only within the last three years that the double-acting type has been seen in America. Originating in England, with the engineering firm of Dick, Kerr & Co., Ltd., of London, it has been in successful use for about ten years.

The essential differences existing in its operation are directly consequent upon the difference in design, and as the single-acting is much older it will be proper to consider that first. In all well known single-acting engines, as now built, the piston is its own cross-head; that is, the connecting rod is pivoted directly into it, and there is no piston rod. While this permits a short, compact machine, it necessitates a heavier construction of piston, and,

what is much more serious, it forces the wear of the " angle thrust " of the connecting rod on to the bottom of the cylinder.

In small engines, when well lubricated, this is not a serious matter, because the heats are not so great as to impair the lubrication, and the weights and pressures do not exceed the cylinder's wear-resisting qualities; but in large engines the conditions are different, the power of the impulse and angle thrust, and the necessary weight in the piston and connecting rod, increasing very much more rapidly in proportion than the wearing surface on the bottom of the cylinder, together with which is the increasing difficulty of proper lubrication in the greater volume of heat. All these causes, working together, seem to fix the practical limit of the single-acting engine at about 16 inches diameter of cylinder, corresponding to about 75 indicated horse-power. Larger engines of this type have been built in Europe, but they have not, so far as is known, become commercial factors.

The regulation of single-acting engines for electrical work presents much difficulty. The maximum of explosions being one in four strokes, on anything less than full load frequently eight or even twelve strokes intervene between explosions. This irregularity has, to some extent, been overcome by the use of heavy fly-wheels and high speed in the engine, supplemented generally with a countershaft carrying a solid or a spring balance wheel and the belting done from that to the dynamo.

In this manner, through the inertia of the wheels and the elasticity of the belts, a fair degree of steadiness has been obtained, but necessarily at an expense of power and floor space. The difficulties in the way of sensitive regulation of the engines are twofold:—First, the long interval between impulses; second, the inherent irregularities in mechanical governors themselves, due to inertia, friction, uneven lubrication, wear and actual work frequently to be performed.

In turning to the double-acting engine of ordinary construction we find many of the same difficulties that are encountered in the single-acting, except, that they are greatly modified in their effect. The practical result of this is to permit the engine being built to very much greater powers, the exact limit of which we do not know, but can safely state it at not less than 500 I. H. P. in a single cylinder. This increase is simply illustrated by saying that if a 16-inch cylinder will develop about 75 horse-power in a single-acting engine, and if the same pressure is applied to the return stroke, making it double-acting, we will get 150 horse-power, and this is approximately true. But there are other conditions which greatly increase the power possibilities of this type.

In the first place, the piston for the same diameter of cylinder is much lighter, having nothing to carry, and, being strongly bound together on a piston rod, one-half of the weight of which, and all the angle thrust of the connecting rod, being carried by the crosshead in the frame where wear and lubrication present no difficulties. The heats upon the piston and cylinder are uniform, and a special construction of the piston can be used, which provides for a considerable amount of expansion in it, with the result that these engines have so far been built as large as 25 inches in diameter, and in this size have produced 280 horse-power on producer gas, corresponding to 325 horse-power on coal gas. The particular engine referred to was completed in October, 1894, and has since been in operation, driving a weaving mill, in Lancashire, England.

I must condense mention of the other prominent advantages of double-action by saying that it is possible with it to obtain two impulses instead of one; that these impulses are of half force, comparatively, to the total power, and consequently produce less shock to be absorbed by the fly-wheels; hence a lighter fly-wheel and lighter working parts throughout are possible; the wear on all journals and bearings is equalised, while the wear of the piston on the bottom of the cylinder is no more than in steam engines of equal diameter.

The question of governors does not

seem to have had the consideration due it. Perhaps it would be more correct to say that its paramount importance has not been appreciated. Until recently the gas engine in large units had not been deemed a serious commercial quantity. Latterly it has forced its way to recognition, but still no such general study has been accorded the philosophy of it, as to the steam engine or the electric motor. While the improvements in detail and construction have been great, no radical advancement has been made upon the principle and type of twenty years ago; and, perhaps, the governors have kept pace in that respect.

The gas engine governor deals with a kick or blow which must be anticipated by three strokes to be prevented or permitted. Therefore, it should be sensitive to the slightest variation in speed; should magnify and indicate such variation instantly; hence, must be too light to exert any power whatever, and must operate in conjunction with an actuating power capable of responding instantaneously to its indication. These remarks apply with greatest force to the "hit-and-miss" principle of admitting charges, and which is practically the one in universal use. The "variable charge" type is mentioned later.

Realising this, an exhaustive series of experiments were undertaken in regulation for electric work, using the "hit-and-miss" and "non-variable charge" principle. These experiments may be divided into three classes. First, permitting the engine to run as it would with its mechanical governor, and automatically introducing resistance into the dynamo circuit to prevent the voltage rising above normal. Second, maintaining the voltage of the circuit by a varying speed of the engine according to the load. And, third, maintaining a constant speed upon the engine by its own governor, and applicable to any class of work. The final result only was practical, and should perhaps have been the first attempted, but it is due to the others to say that they indicated the means by which the last was accomplished, and this certainly promises all that could be desired on the "hit-and-miss" principle.

In the matter of regulation, it has been determined, by tachometer readings, that this governor controls a 130 indicated horse-power engine, installed at Lancaster, O., in July last, within 3 per cent. total speed variation from no load to full load. That is, 1½ per cent. above or below the normal of 180 revolutions, and positively prevents any semblance of racing. It must not be inferred from this statement that the engine actually varies five and one-half revolutions in speed in different minutes. A speed indicator will count the normal number of turns, minute after minute, with scarcely a variation, and it is only by tachometer readings that the variations in the rate of turning can be observed.

The instantaneous response of this engine through its governor, from no load to above its maximum capacity, should have attention in comparison with the more gradual recovery of a steam engine. I think this regulation will compare favourably with that of the best steam-driven service.

This engine has been in daily operation eighteen hours per day, with very few shut-downs, and none that were not directly due to small adjustments in mechanical details or to inexperience on the part of the operators, to whom the requirements of this class of work were entirely new, and having been carrying this load under these conditions for seven months, it would seem reasonable to have confidence in it.

Another engine of the same size and type has recently been installed at Marietta, O., which is to also drive a street railway plant in connection with a similar engine of about 90 horse-power, these two being a preliminary equipment.

The variable charge governor, previously mentioned, is on a radically different principle. Mr. John Hartley some years since devised a governor of this type which was styled an "electric lighting governor." This is a most ingenious mechanism for proportioning the amount of charge to the work in

hand. Within its range it is very effective. It is, perhaps, the highest expression of the theory of economical use and effective governing by a strictly mechanical means of which the Otto cycle is capable. Improvements have been made in it of late which have increased its regulation from practically no load to full load without misses, but with what changes in construction I have not yet learned. A plant of about 750 horse-power, in four 120 horse-power tandems, and two 60 horse-power single engines, fitted with this governor and installed for the corporation of Belfast, Ireland, has been in use, driving Siemens & Halske dynamos, for something over two years with very satisfactory results.

Related to the question of regulation, and in reality an outgrowth of the attempts to secure it, are to be classed the various makes of multiple-cylinder engines, generally of the vertical type, which, with high speed, endeavour to overcome the ordinary irregularities. In small sizes some of these have met with success, but if attempted in large sizes it would seem that the number of bearing surfaces and the piston friction would be objectionable.

In the double-acting horizontal type this attempt has resulted in the tandem engine—a second double-acting cylinder placed in line behind the first, similar to a steam engine. This produces, at full load, an impulse to every stroke, gradually reducing, on the hit-and-miss principle, at one-quarter load to an impulse every fourth stroke (same as single-acting full load). When this type is fitted with the Hartley governor it produces the extreme of close, economical regulation.

As beyond the province of the governor, dependence must be placed in the fly-wheels for the two purposes of absorbing the sudden fluctuation, and of carrying the engine over any undue instant increase in load.

The Lancaster engine, indicating 130 horse-power, has 13,000 pounds of fly-wheel. This weight is 100 pounds of fly-wheel per horse-power. Comparing this with steam engine practice, I had recent opportunity to examine one of the latest steam engine plants with tandem compound engines, made by the E. P. Allis Company, and using Siemens & Halske dynamos, direct connected. On each engine the fly-wheel and armature together weigh 82 tons; figuring this out, we have 104 pounds of fly-wheel per horse-power, and taking a direct comparison from the dimension table of a well known builder of Corliss engines, I find that an 18×36 engine, running 80 R.P.M., developing 129 indicated horse power at one-fifth cut off on 80 pounds steam, has a belt fly-wheel weighing 13,000 pounds, or 100¾ pounds per indicated horse-power. The tendency in street railway practice appears to be towards increasingly heavier fly-wheels with a marked tendency to slower speeds.

THE PURIFICATION OF LUBRICATING OIL.

By G. W. Bissell.

THE term purification, as used in this paper, is applied to any operation employed for reclaiming waste oil from the bearings of machinery so that it may be used again on the same or other bearings. The object of purification is the reduction of the expense of lubrication. Sometimes new oil is treated by a purifying process to rid it of mechanical impurities, some of which are inherent, but most of which are acquired by the oil in handling or in standing in receptacles from which dirt is not excluded.

The utility of purifying waste oils is recognised, and purification is extensively practiced by the managers of all well-conducted machinery plants. There are, however, many plants, especially small ones, where the indifference to this means of securing economy in management is very manifest.

While the practice of saving and reusing oil is very common, the means employed and the results obtained are various. Self-oiling bearings, now manufactured in many forms and very cheaply, were primarily designed to secure reliability of lubrication, but they do, at the same time, reduce very largely the expense of lubrication of machines. They are most generally used in line-shaft work, but their use is extending to the journals of self-contained machinery, notably electrical machinery. The self-oiling principle is well exemplified in the enclosed types of engines now on the market.

Aside from the saving of the oil by its re-use, self-oiling bearings accomplish purification to a certain extent—ring and chain oiling devices, because much of the impurity settles to the bottom of the reservoir,—wicks or other capillary devices in a greater degree, because the impurities cannot reach the bearing.

With bearing surfaces so designed and cared for as to prevent destructive action on the lubricant, with lubricants adapted to the existing conditions of pressure and velocity of rubbing, and with ample reservoirs for the oil, the continuous use of a limited quantity of oil in self-oiling bearings gives very satisfactory results. It is good practice to renew the oil at regular intervals and frequently enough to preclude the possibility of failure of the lubricant to keep the work of friction below a safe and economical limit.

The self-oiling principle is not of universal application and there is in all machinery plants a quantity of oil which drips from the lubricated surfaces. Cleanliness and immunity from fire risk demand that this dripping oil be caught or confined in pans, and economy requires its re-use if possible. To permit

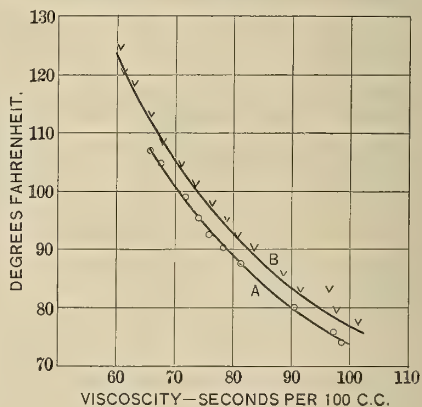


FIG. I.

of this latter, the oil must be freed from its impurities.

The impurities in waste oil from bearings are chiefly mechanical, and consist of dust, grit, water, insects and fine metallic particles removed from the rubbing surfaces by attrition. Chemical

impurities may exist in the form of free fatty acids, liberated by the decomposition of animal oils, and as residue resulting from the burning of the oil by excessive local pressure. The former is quite a common and the latter a rather unusual form of chemical or chemically produced impurity. The effect of impurities upon viscosity, coefficient of friction, specific gravity, and colour of the oil is quite appreciable.

In connection with this, the following results of experiments made by the writer are given. In Fig. 1 are shown two curves, *A* and *B*, of which *A* is the viscosity-temperature curve of a clean unused engine oil, and *B* is the viscosity-temperature curve of some of the same oil which was collected from the bearings of engines and dynamos in the power plant of the Iowa Agricultural College. The ordinates are temperatures in degrees Fahrenheit and the abscissæ are viscosities in seconds obtained with a Pennsylvania Railroad viscosity pipette.

Samples of the same clean and dirty oils respectively were tested on a Thurston oil tester, especially arranged to give a large deflection with light load,

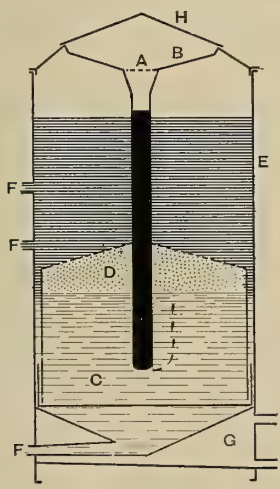


FIG. 2.

with the following results:—With clean oil the temperature became stationary at 116 degrees and the arc reading became stationary at 12. With dirty oil the temperature became stationary at 121 degrees and the arc reading became stationary at 16.

The colour and general appearance of an oil are very decided indications of the presence or absence of impurities. Usually the dirty oil is clouded and darkened and lacks the depth and purity of colour which characterise clean oil. In judging of the necessity for, and the efficiency of, purification we may use tests for viscosity, friction, or colour as a criterion. The colour test is the most convenient and is reliable except in the case of purification by agitation with sal soda, mentioned below, which may darken the oil. The darkening in this case, however, is not accompanied by turbidity; the oil is clear and its colour deep.

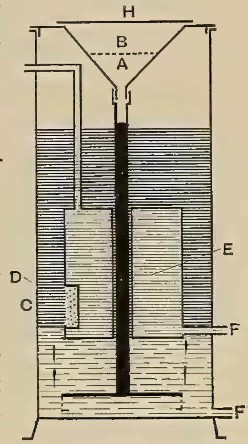


FIG. 3.

The purification of oil may be effected by settling, by percolation, by capillarity, by agitation, by centrifugal action, by chemical action or by combinations of two or more of these principles. Devices for accomplishing purification by whatever principle are commonly called filters. Filters which effect purification by settling are simply settling tanks having large volume relative to the amount of oil in actual use, and considerable depth. The impurities settle to the bottom, some at once, others more slowly, and the upper portion of the tank will, after a while, be found to contain relatively clear oil which can be drawn off for use. Almost complete purification of mechanical impurities can be accomplished by settling if time enough is allowed and care is taken, in adding dirty and withdrawing clear oil, to disturb the contents of the tanks as little as possible.

Purification by percolation is done in filters consisting essentially of a strainer upon which the oil is poured and through

which it passes, leaving the impurities behind. The first attempts at filtering were made with strainers of perforated metal or wire gauze. They abstracted only the gross impurities. The next step in the development of the filter consisted in placing a bunch of waste on the strainer, and successively other and more dense materials were tried with varying results.

At present we find waste, hair-felt, cheese-cloth, charcoal, shavings, sponge, paper and a host of other substances serving in filters of the percolating type. The desirable material for the purpose should be dense, strong, porous, and homogeneous. In the opinion of the writer the best material is blotting paper. It possesses all of the required qualifications, except strength, and this is readily supplied by a support of wire gauze or perforated metal.

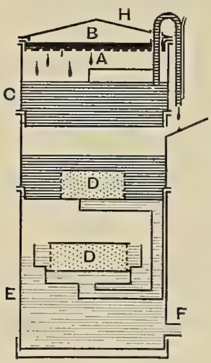


FIG. 4.

Capillary filters are those in which the oil is separated from its impurities by the capillary action of a wick of cotton, or other material. The principle is old, as applied to lamps and to wick-feed oiling devices for machinery, but has not been extensively used in oil purification. The capillary filter has certain advantages over all other types. It is impossible to rush the operation, and destruction of the wick does not result in a deluge of dirty oil into the clean oil reservoir. The wick will stand longer usage without cleaning or renewal than will the filtering medium in the percolating filter.

Purification by agitation consists in forcing the dirty oil through a body of water or in mixing the oil and water by shaking. Settling is an essential subsequent operation. Agitation is a secondary, and not a salient, feature in commercial filters.

Machines are on the market for the separation of oil from metal chips and turnings. The centrifugal principle can be used also for the separation of oil from the impurities which are found in waste oils. The writer has used the process experimentally and with success, but the power required is out of proportion to the quantity of oil handled. But the method promises well for the separation of cylinder oil from condensed steam or from the drip from exhaust steam eliminators.

Chemical action may be advantageously used with most waste oils. By the agitation of the oil with a solution of sal soda the free fatty acids contained in the oil are removed. Sometimes the result is also a darkening of the oil.

Any of the above mentioned principles of purification can be followed singly with advantage by the user of oil for power purposes, but inspection of filters on the market shows that two principles are usually employed in combination. For example, percolation is usually preceded by settling; settling is usually assisted by agitation. In all cases where settling or percolation is used, the heating of the oil is an advantage, hastening settling in the one instance and expediting the filtration in the other. The heating is most readily accomplished by performing the settling over a body of water which is heated by a coil of pipe through which live or exhaust steam is circulated.

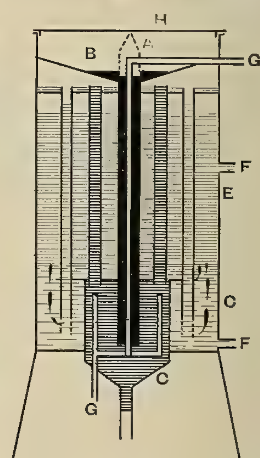


FIG. 5.

Where agitation is employed, the oil is very effectually heated by its thorough admixture with hot water, heated as above indicated.

Figs. 2 to 6, inclusive, show in diagram, but not in mechanical detail, the construction and method of operation of several devices now on the market for the purification of oil. There are many

besides these, but the ones selected are typical. In all the figures the following nomenclature is used:—*A*, strainer for insects, bits of waste, etc.; *B*, receiver for dirty oil; *C*, settling chamber; *D*, percolating material; *E*, storage for purified oil; *F*, faucets for oil or water; *G*, device for warming the oil; and *H*, cover for excluding dust. Dirty oil is represented by solid black; clean oil and water by horizontal continuous and broken shading respectively.

Fig. 2 is the diagram of a percolating purifier in which percolation is preceded and succeeded by settling over warm water, the same mass of water serving for both the antecedent and the sub sequent settling.

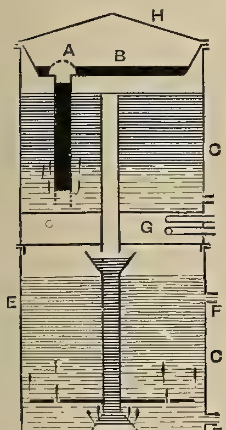


FIG. 6.

The percolating medium is hair-felt and fine charcoal. The warming of the water is done with exhaust steam in the manner shown by the drawing.

Fig. 3 shows an apparatus in which percolation is the distinctive feature, but is preceded by settling. The percolating medium is close-textured sponge and is clamped over circular openings in the side of the storage tank *E*.

Fig. 4 shows a filter in which no water is used and the oil passes through two percolators. The floating syphon for drawing the oil from the settling tank draws always from the top of the oil and delivers to the chamber below at a definite rate, irrespective of the amount of oil in *C* or the quantity thrown into *B*. This device also indicates the amount of oil in *C*.

Figs. 5 and 6 show two forms of purifiers or refiners in which purification is accomplished by settling and agitation, aided by heat. In Fig. 5 settling takes place, first, in the oil itself, which is warmed to accelerate the process, and, again, over water in the large settling chamber *C*. In Fig. 6, settling with agitation occurs twice, once over warm water, and once over cold water. All of the above mentioned filters or purifiers are, in actual construction, much elaborated with water glasses, bibbs and other devices for ascertaining conveniently the condition of working, and to facilitate cleaning. One manufacturer constructs the whole apparatus of glass.

As to the relative merits of the above and other devices for purifying oil, the writer, after experiment and experience with numerous filters and purifiers, manufactured and home-made, as well as with special apparatus, constructed for study of specific features of the subject, has come to the conclusion that very nearly equally good results can be obtained with filters and purifiers by giving to each a fair amount of care. All forms are easily pushed beyond their capacity. Percolating filters are liable to give trouble by filling up of the filtering substance. Settling filters give poor results if large quantities of oil are fed at one time.

It would seem that all filters and purifiers should comply with the following conditions:—The flow of dirty oil from the receiving chamber to the settling chamber, or from the settling chamber to the other compartments of the apparatus should be uniform and automatically independent of the quantity of oil in either *B* or *C*. This is best accomplished by the floating syphon, mentioned in connection with the filter shown in Fig. 4. The capillary filter complies perfectly with this requirement.

All percolating or filtering material should be readily and quickly renewable and should not be special in its nature or preparation. Ordinary blotting paper for the one, and lamp wicks for the other, are excellent materials.

All purifying operations should be conducted with the assistance of heat.

Where oils contain animal oils, free fat acids may exist in the dirty oil and should be removed by agitation with sal soda. All parts of the apparatus should be thoroughly cleanable, and water glasses and bibbs provided to show the level of each mass of liquid.

THE EVOLUTION OF THE BRITISH COASTING STEAMER.

By J. S. P. Thearle.

WHENEVER a special kind of vessel is found to be invariably employed by the people of a maritime district for the performance of the cargo-carrying or other service demanded by the products or industries of the country, it may safely be inferred that the form in question has been evolved from others, less suitable, and that it is, in fact, the survival of the fittest. Generally, too, we may further infer that, under all the circumstances bearing upon the case, the surviving type of vessel is the best possible for the people who use it.

The general form and rig of the Thames and Medway barge have remained unchanged during many generations and will probably endure so long as the conditions of navigation on those rivers continue as they have been and still are. The Thames wherry is utterly unlike the Deal pilot boat, and both differ from a Gold Coast surf boat, while all three are crystallised developments, along different evolutionary lines, of the primitive log canoe. The Shields brig and the Brixham schooner were both, in their way, the highest results of the shipwright's and rigger's skill in their endeavours to meet the requirements of the trades in which these two types of coasting craft were engaged. Each

A MODERN BRITISH COASTING STEAMER.

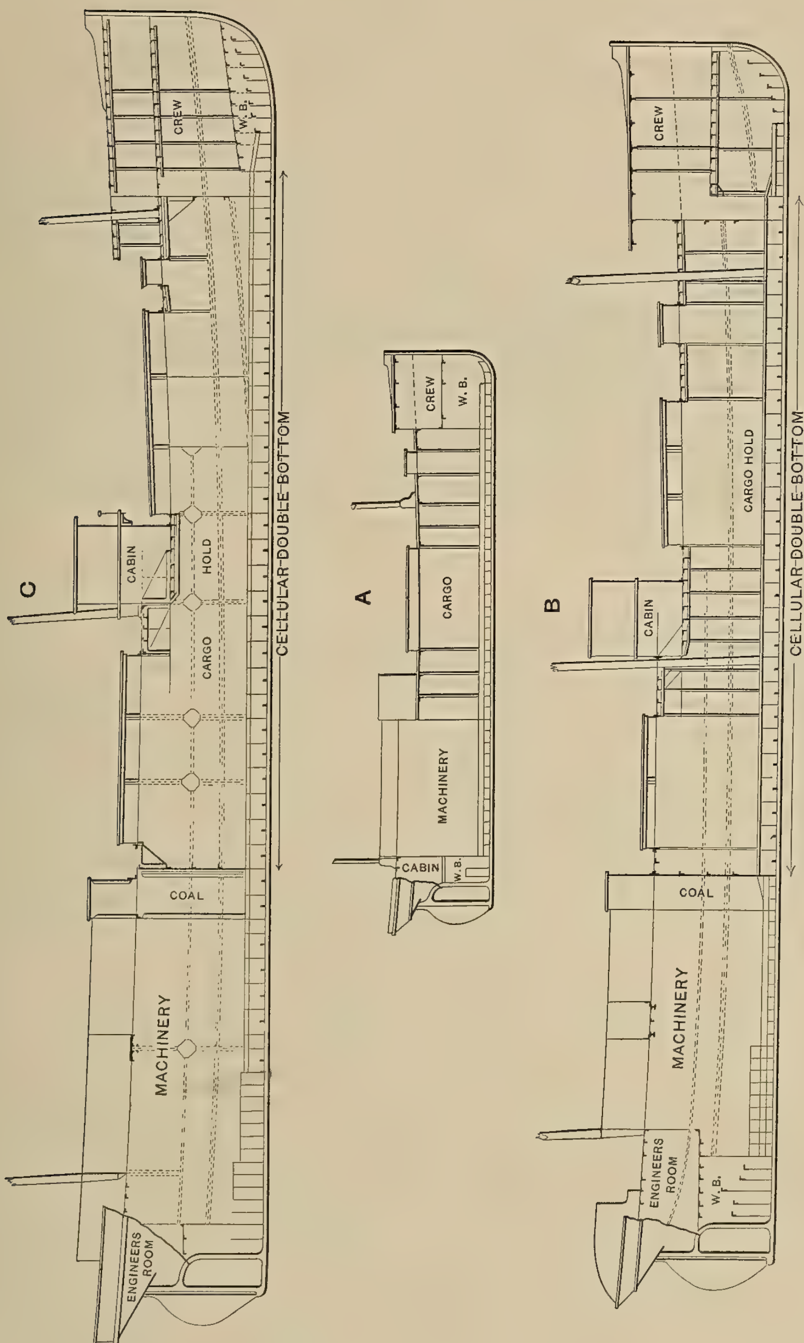
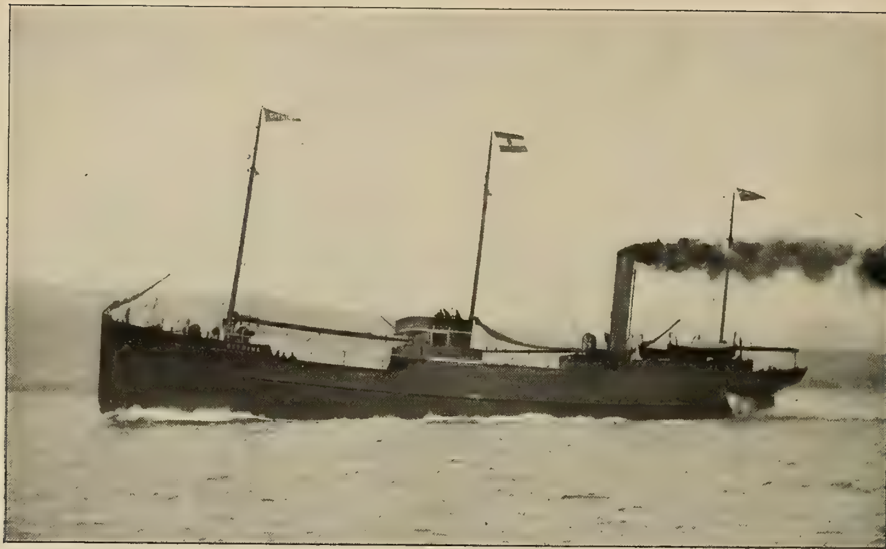


FIG. 1. EARLY AND MODERN TYPES OF COASTING STEAMERS.



ANOTHER TYPICAL DESIGN.

survived all pre-existing forms and rigs in their respective waters, and each was ultimately represented by hundreds of little vessels which scarcely differed from one another in any appreciable particular.

Then came the marine engine and the iron ship, and to both were added possibilities in the cheap and speedy carriage of goods around the coasts which rendered brig and schooner no longer the best possible craft for the work they had been doing. From that time a new type of coasting cargo carrier came into being, and during the intervening years we have been enabled to witness the evolution of the British coasting steamer.

It was about fifty years ago that the coast-carrying trade from the Tyne to London was first undertaken in small steamers. For a long time the Eastern brig and the Western schooner struggled to make a living alongside their steam-driven competitor, and even to this day a few of them remain afloat. Here and there the exigencies of small harbours and out-of-the-way markets give sailing coasters a bare employment; but they are rapidly disappearing, and as they founder or decay, few others are built to take their places. The old order has passed away and the new is being perfected.

It would be rash and unscientific to assume that the most modern form of the coasting steamer has attained to that degree of permanence which so long characterised the brig and schooner; but the improvements already effected have been so marked, and the state of efficiency now reached is so high as to make the modern coasting steamer of the British islands a subject of interesting and profitable study.

The screw colliers, carrying coals from the Tyne to the Thames, were the first British coasting steamers. So far back as thirty years ago a considerable number of these vessels was at work, and in them was to be found the germ of the cellular double-bottom which now constitutes a very important element in a seagoing cargo steamer.

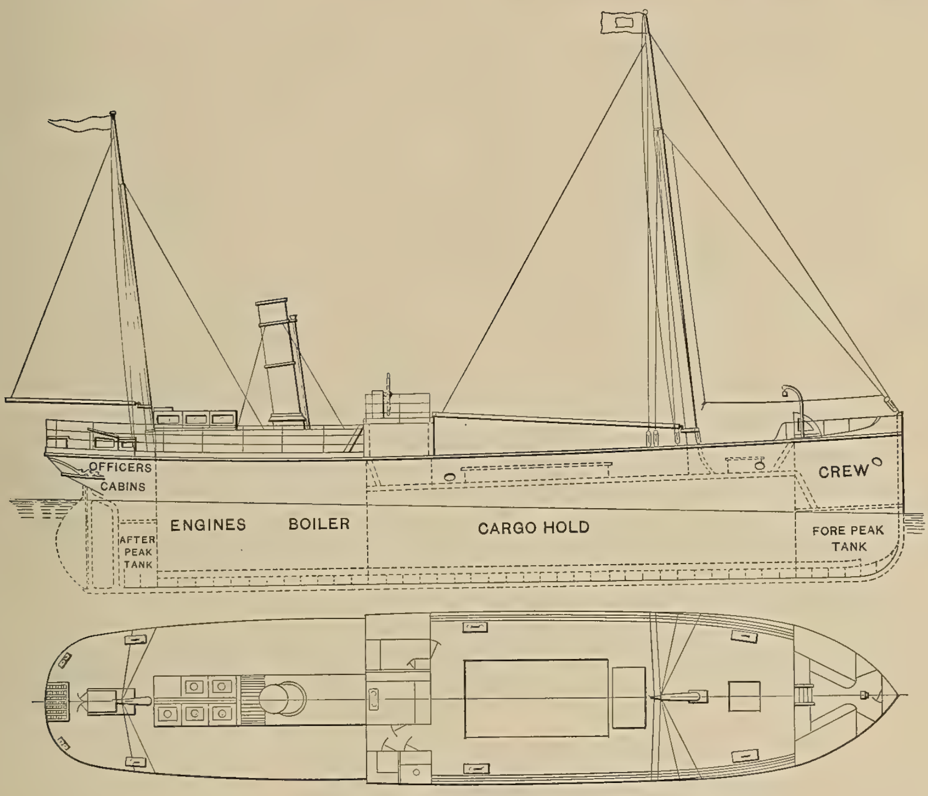
The vessel taking coal to London had, of necessity, to return in ballast, there being but little produced on the Thames for which there was a market on the Tyne. Iron lends itself most conveniently to watertight construction, and so, when iron steamers displaced wooden brigs in the coal trade, it speedily occurred to an ingenious shipbuilder

that iron water tanks might be put into the bottom of the vessel and that these tanks might be filled from the sea and pumped out by the engines.

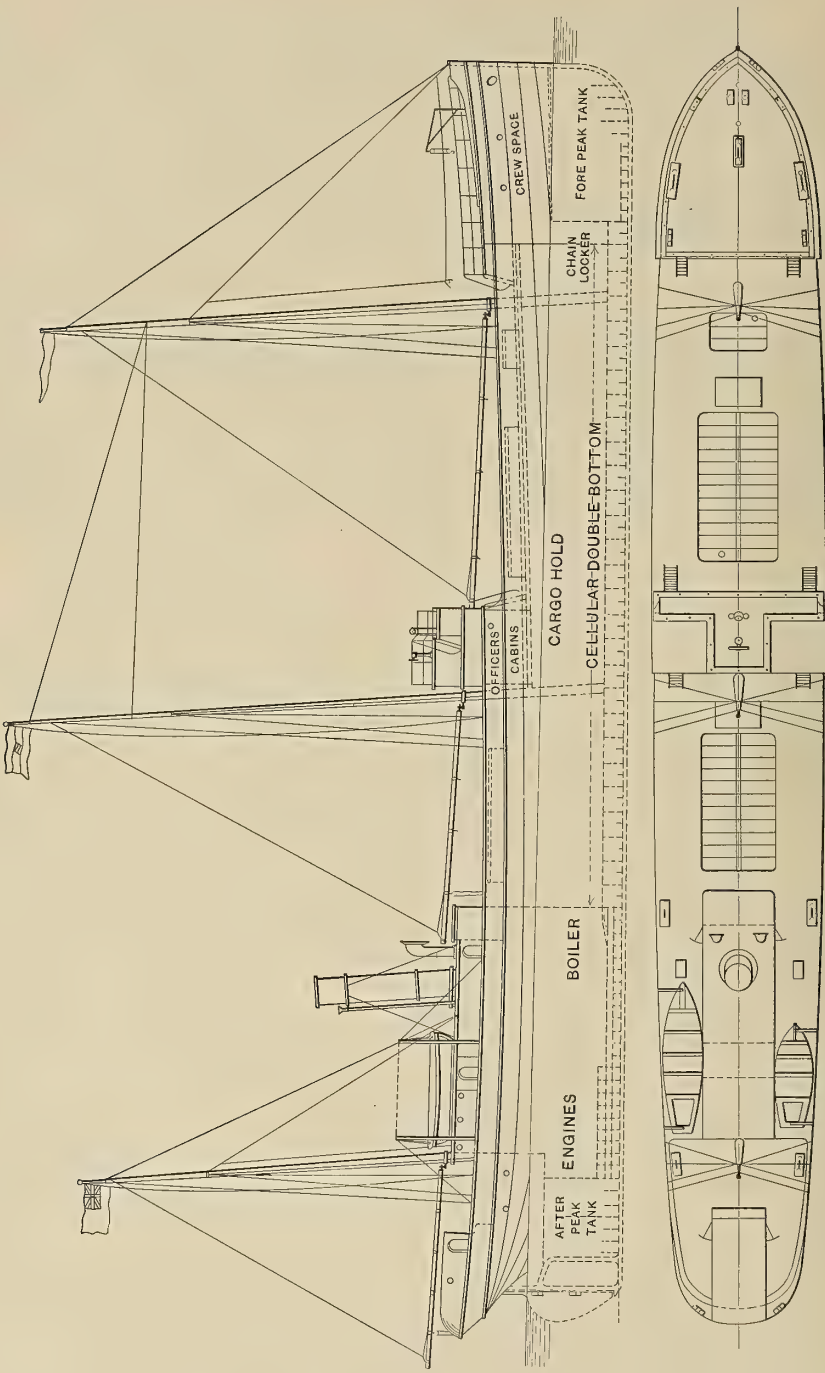
At first the ballast tanks were independent of the structure of the hull; but very soon the bottom of the vessel was utilised as the bottom of the tank and an inner bottom, placed a foot or two above the level of the floors, formed the tank top. This arrangement, which is known as the McIntyre tank, was soon followed by the cellular system of construction, which, in its various forms, is so prevalent to-day. What was at first devised for water ballast purposes alone, has grown into a structural arrangement of the highest value.

The Tyne screw colliers have not, in recent years, diverged much from the parent type. They carry but the one cargo, viz., coal, which does not necessitate long, unbroken cargo spaces. Moreover, the harbours which they frequent, enable them always to load and discharge afloat, and consequently their structures are not exposed to the severe stresses to which sometimes those steamers are subjected that load and discharge in tidal harbours.

The vessels which form the subject of this article carry all descriptions of coasting cargoes to and from ports and harbours of the most diverse description, such as are found on the extensive coast line of the British islands. They must be able to stow and carry coals, limestone, china clay, iron ore, pig iron, cement, manufactured iron and steel in the form of rails, plates, girders, etc., and other forms of deadweight cargoes. They must be able to enter all ports and harbours wherever cargoes are waiting or wanted, and they must be strong



FIGS. 2 AND 3. AN EARLY DESIGN.



FIGS. 4 AND 5. A LATER TYPE OF COASTING STEAMER.

enough to lie during one or two tides either with cargoes in or out, upon ground hard or soft, with bottoms dry or partly waterborne.

Besides these requirements they must trim satisfactorily when either loaded or in water ballast; must be seaworthy in all weathers, easily driven and steered, quickly loaded and discharged, and not too often laid up for wear-and-tear repairs. Comfortable, dry and warm accommodation must be provided for crews which have no long period of rest ashore; for, be it understood, the coasting steamer must be ever on the move countered in the evolution of the coasting steamer and to state their solution.

The Clyde is the birthplace of the special vessel under consideration, and it is on the Clyde that it has developed into its present form. The "Gem" fleet of Mr. William Robertson, of Glasgow, contains nearly the entire series of evolutionary growths and its highest development. The little shipyard of the Scotts, at Bowling, has been the chief scene of the problems as presented on their repairing slipway, and of the solutions effected in succeeding vessels on the building blocks.

SOUTHWARD BOUND WITH A CARGO.

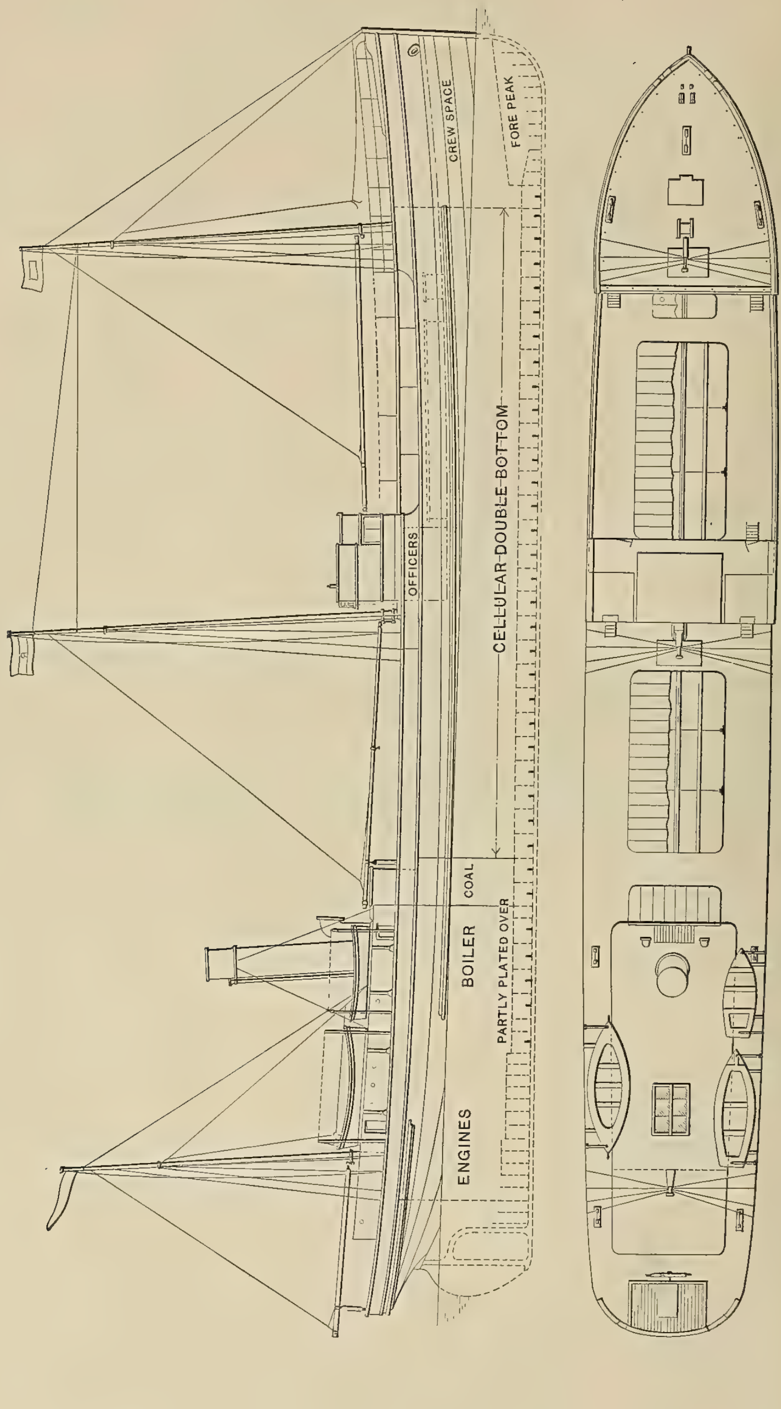
and carrying freight if, with the prevailing low rates, a profit is to be earned on her first cost and up-keep.

These are some of the conditions to be fulfilled, and it is not pretended, with all the improvements in them which have been made during the past ten years, that finality has been reached or perfection attained. All that can be claimed is a continuous development and a closer and closer approximation to the perfection and permanence of type that may yet be reached.

It is a chief object of this article to indicate the successive problems en-

The trade in which these vessels are employed is unlike that of the East Coast collier in so far that, instead of making one-half of their voyages in ballast, they frequently find a cargo at or near the port of discharge, to be delivered at their home port or some other place on the coast. Hence, they are generally laden when at sea and do not often require to be stiffened with ballast.

The earliest of these vessels (see *A*, Fig. 1) were, in consequence, constructed with no other water ballast arrangements than are afforded by tanks in the forward and sometimes in the after peaks.



FIGS. 6 AND 7. THE MOST MODERN DESIGN.

These were, however, relatively capacious, and, in the case of the fore peak, often extended to nearly the full depth of the hold. With the proportions adopted in the design (see Figs. 2 and 3) sufficient stability was thereby afforded for safely navigating the unladen vessel to the place where the cargo awaited her.

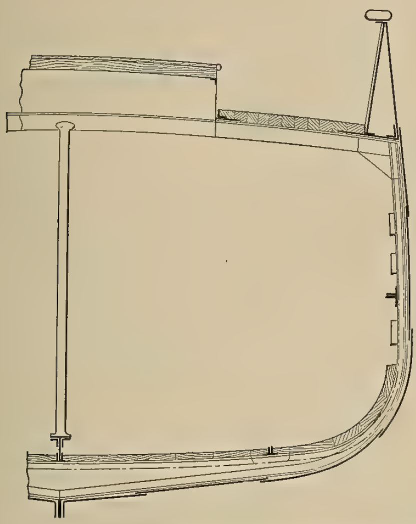


FIG. 8. A MIDSHIP SECTION OF STEAMER *A*, FIG. 1.

At first the coasting steamer was merely a dwarfed imitation of the ordinary "tramp," with a forward and an after hold and with machinery amidships. But the errors in the arrangement very soon disclosed themselves. The holds were each too short for stowing railway and other bars, and the necessary shaft tunnel cut off a large fraction of the stowage in the after hold. Hence, almost from the commencement of its existence the coasting steamer was designed with engines and boilers at the after extremity and with one long cargo hold extending from the forward bulkhead of machinery space to the collision bulkhead or fore peak tank (see *A*, Fig. 1; also Figs. 2 and 3).

Partly in order to afford enough depth to house a large boiler and the vertical inverted type of compound engine, and partly with a view to trimming the vessel satisfactorily when laden, a raised quarter-deck type of steamer was at the same time adopted and this type—now known as well-decked—has been retained to the present day. As safe sea going vessels they have well justified the wisdom of their first designers, but the inherent tendency to weakness, due to discontinuity of the structure at the break of raised quarter-deck, has imposed upon more recent builders the task of obtaining continuity of longitudinal strength at that part without sacrificing in any way the efficiency of the type (see *B* and *C*, Fig. 1).

The vessel marked *A*, in Fig. 1, and shown both in profile and plan in Figs. 2 and 3, is one of the early coasting steamers. Figs. 4 and 5, and *B* in Fig. 1, show in profile and plan a further development as attained about ten years ago, while Figs. 6 and 7, and also *C* in Fig. 1, represent the most modern and perfected stage in the evolution towards a permanent form.

At a first glance it might be thought that there is very little difference, except in relative size, between these vessels. And, indeed, it is only when the details

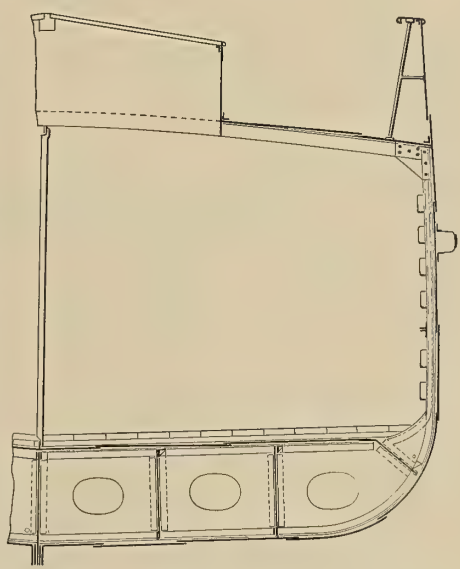


FIG. 9. A MIDSHIP SECTION OF STEAMER *B*, FIG. 1.

in the structures of the vessels are compared that we are able to fully recognise the nature and extent of the advances made between the earliest and the most

recent. But even in their longitudinal outlines there are revealed to the skilled eye some noticeable developments.

The early vessel has a small sheer, comparatively short raised quarter-deck, no bridge house, large fore-peak tank, tank in the after-peak, crew's forecastle wanting in room and protection, accommodation for the officers far from the navigating bridge, pillars and masts breaking the stowage space in hold, and comparatively shallow floors. The most recent have a considerable sheer, longer raised quarter-deck, roomy bridge houses, very small fore-peak tank and no tank in after-peak, roomy, comfortable and sheltered crew's forecastle, officers' cabin close under the navigating bridge, no pillars nor masts in hold, and a strong structural double-bottom girder upon which to rest when aground. These differences are visible in the profile views alone; but when we compare the transverse sections of the earlier and later vessels, the improvements effected in the evolution of the type are far more distinctly apparent.

Fig. 8 shows a half midship section of the vessel represented by *A*, Fig. 1, and Figs. 2 and 3. Fig. 9 is a half midship section of the more advanced type represented by *B*, Fig. 1, and by Figs. 4 and 5. In Fig. 10 we have a half midship section and a half section in way of raised quarter-deck of the vessel shown by *C*, Fig. 1, and by Figs. 6 and 7. Many important features not seen in either of these plans will be alluded to presently.

It will, perhaps, be convenient if we take separately under consideration the various problems which have presented themselves in the development of these vessels. The service which they have to perform has already been briefly indicated, and it is necessary to keep these before the mind in considering the successive stages of progress made in better fitting the steamers for their work. The service is necessarily an arduous and a trying one. The cargoes are mostly dead weight; the steamers are at work in all weathers, in winter and summer, navigating narrow waters and continually entering and leaving harbours, some easy and others difficult of access, some with deep and others with shallow entrances; loading and discharging sometimes afloat and very often on the ground. To receive certain kinds of cargo and to rapidly load and discharge

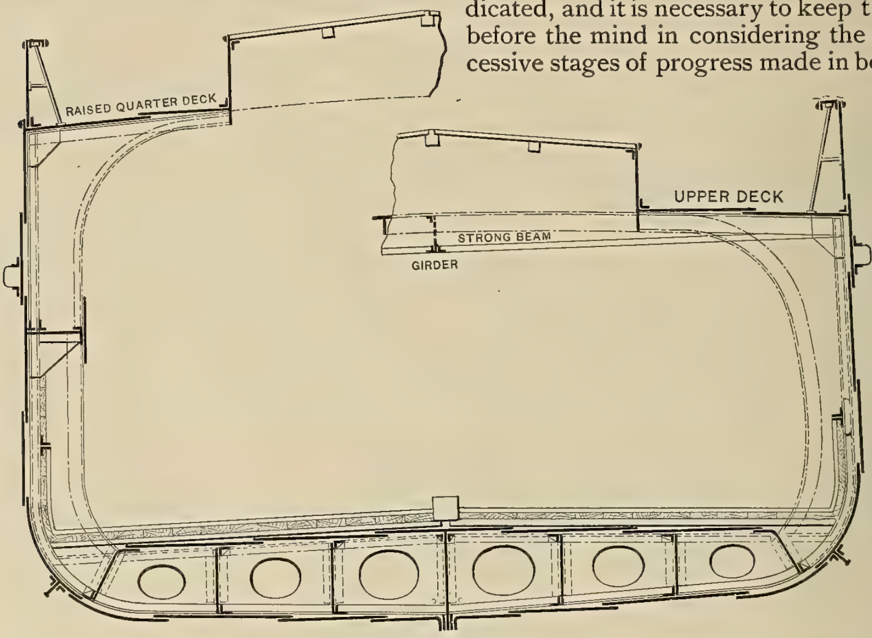


FIG. 10. CROSS SECTION, SHOWING CELLULAR SYSTEM OF FRAMING.

all kinds, large hatchways are necessary and the hull has to be so constructed as to be sufficiently strong in spite of large openings in the deck. Everywhere the vessel must be strong enough to do hard work and endure hard knocks, whether at sea or in harbour.

The decks are of iron, that material being preferred to steel because it does not corrode so rapidly when exposed to spray from the sea constantly falling upon a surface unprotected by paint.

To stiffen the sides of the steamer in the way of the large openings in the deck, web frames were introduced about twelve years ago, and still more recently the pillars which supported the sides of these long hatchways, being in constant danger of bending or fracture through blows from the cargo, were replaced by arched continuations at the tops of the web frames, as shown in Fig. 10.

Continued lengthening of the hatchways has been accompanied with additions to the number of these arched web frames and with arched brackets attached to ordinary frames at the ends of the hatchways (see *A*, Fig. 12). This numerous series of web frames and brackets throughout their length has made these vessels well able to endure the frequent squeezings and rubbings which they encounter against wharves and quay walls, besides enabling them to resist the racking stresses to which they are exposed in a sea-way with a dead weight cargo on board.

Grounding in tidal harbours, and having often to do so with a cargo on board, proved, from the first, a serious element of risk in the working of these vessels. So often were they found in dry dock with their bottoms set up, pillars bent and broken and the framing and plating of bottoms distorted and torn, that the ordinary framing of an iron ship (Fig. 8) had to be abandoned for a stronger structural arrangement.

This was found in the cellular system of framing (Figs. 9 and 10), which further afforded the advantage of a higher floor upon which to rest a dead weight cargo and thereby raise its centre of gravity. The modern coasting steamer has a double bottom as deep as is found in seagoing vessels of much larger size, and in order to obtain the consequent strength and stability advantages without employing an undue weight of materials, the "floor at alternate frame" system is chosen. Fig. 10 shows the floors at alternate frames and Fig. 12, *A*, shows the intermediate framing. This system has been found to yield the necessary structural and local strength for grounding purposes, either laden or light, and has required but slight additions in order to adapt it for all the stresses brought upon the bottom when at sea.

This brings us to a consideration of one of the most interesting problems encountered during the perfecting of the coasting steamer. Soon after the application of steel in their construction, with the consequent diminution of thickness allowable with that highly tenacious material, it was found that the forward part of the bottom of these vessels, from a few feet before the collision bulkhead to about ten or twelve feet abaft, became, after a few months' work at sea, very much more corroded than elsewhere. The countersink points of the rivets were found pitted, the rivets sometimes were loose, and the shell plating was so much set in between consecutive floors as to suggest that the vessel had been ashore. Associated with this phenomenon was a wasting of the lower edges of the outer strakes of plating at the same part of the bottom, and this wasting proceeded at such a rapid rate that after two or three years' service it had extended to the rivets in the lap of the plate edges.

Considered by itself, the setting in of the plating between the floors and the loosening of the rivets attaching it to the frames, seemed to point to a straining effect due to the weight of the large body of water carried in the fore-peak tank for trimming purposes when steaming without cargo. Measures were at once taken for reducing the depth of the fore-peak tank (compare *B* and *C*, Fig. 1) and for affording a stronger connection between the peak bulkhead and the hull of the vessel. But, despite continued efforts in both directions the mis-

chief still went on, until the wasting of the plate edges and the corrosion of the rivets suggested that some other cause was at work than had at first been suspected.

It was ultimately discovered that although an undue and, as it turned out, unnecessary weight of water in the forepeak tank had produced some straining

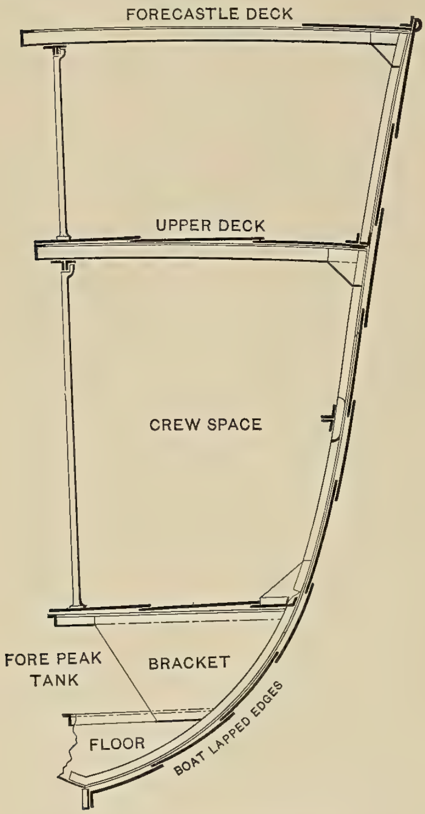


FIG. 11. FRAMING OF FORE PEAK TANK.

effect in the vicinity of the peak bulkheads, yet the principal cause of the phenomenon was the violent pitching movement of the vessel when driven head to sea in a light condition. For, with the machinery right aft, the vessel necessarily trims by the stern, even with the fore-peak filled with water. Whether that tank be large or small, the pitching motion, when driving head to sea, is a frequent one, and the forward immersion being but small, it follows that the comparatively bluff bow repeatedly rises and falls with a thump on the approaching sea.

The relatively thin steel plating was thus, in the course of time, set in between consecutive floors, while the atmospheric air, imprisoned between the "luff of the bow" and the sea at every plunge, acted corrosively upon the surface of the plating and the countersunk points of the rivets and the lower landing edges of the outer strakes in the same way as it does upon the forward upper edge of a screw propeller blade.

When once the cause of the mischief was discovered, a remedy was speedily found. Floors at alternate frames, while sufficiently close at the other parts of the vessel on the fore side of the machinery space, were evidently too far apart to properly stiffen the plating where these blows were received without something more rigid than an ordinary frame angle between them. Hence the intermediate frame angle bars were replaced with six-inch bulb angles throughout that portion of the length of the bow where the mischief was found to extend. (See fore end of double bottom at *C*, Fig. 1, also the framing at *B*, Fig. 12.)

For the rest, the shell plating was increased at the bow to at least the same thickness as in the same strakes amidships and the edges of the troublesome strakes were arranged in boat plank fashion as shown in Figs. 11 and 12. In this way the plating was sufficiently stiffened to stop the vibratory movement that had loosened the rivets, and sufficiently thickened to allow a deeper and better countersink for those rivets. Moreover, the imprisonment of air bubbles at the landings, with the consequent wasting by corrosion, was prevented and the evil was cured. The plating still rusts more readily there than elsewhere, but this is remedied by frequent painting.

It had always been a difficult matter to keep the pillars of these vessels straight and maintain the fastenings at their heads and heels, more particularly in the way of the cargo hatchways. Indeed, the vessels were rarely found, when in dry dock or harbour, without a large

percentage of their pillars either broken, bent or otherwise inoperative. This was inevitable, having regard to the nature of their cargoes and the frequency with which they were loaded and discharged. The pillars abreast the hatchways were usually secured at their heels to a side stringer and consequently gave but a partial support to the deck beams and hatch coamings.

Even when so arranged they were frequently knocked away, broken or bent. The substitution of arched knee continuations at the upper part of the web frames, abreast the hatchways, for these pillars has already been alluded to. The pillars under the deck beams between the hatchways were, however, as seldom found sound and efficient as the others. The fact is, they were not only easily knocked away when handling pig iron, rails, etc., but they were found to interfere with the stowage and carriage of these and other descriptions of cargo. A clear hold, without block or impediment either by pillars or masts, from the collision bulkhead to the stokehold bulkhead, was what the owners of these vessels wanted, provided it could be obtained without sacrifice of strength and efficiency. The solution was found in the arrangement indicated in *C*, Fig. 1, Fig. 10, and, in part, in Fig. 12.

These illustrations do not require much explanation. They show a steamship, formed, so far as regards her cargo hold, with a strong cellular double-bottom girder below, a series of rigid hoops extending from it and stretching transversely across the vessel at five or six places, a centre girder at the top, joining the hoops, longitudinally, to each other and to four transverse bulkheads, and with all these are associated the ordinary frames and beams, and the shell plating and deck plating of the vessel. The result has proved in every way efficient and satisfactory. Instead of pillars which were rarely in place, there is now a permanent and strong arrangement which, when the mast heels are housed, as shown by *C*, *Fig.* 1, leaves a perfectly clear and capacious cargo hold. It should be explained that *C*, Fig. 1, shows the web frames and stringers at the side of the vessel.

The framing of the fore-peak tank is worthy of attention (see Fig. 11). This bracket arrangement affords strength where much needed in vessels of this type, and for tonnage measurement is treated as a portion of the cellular double bottom.

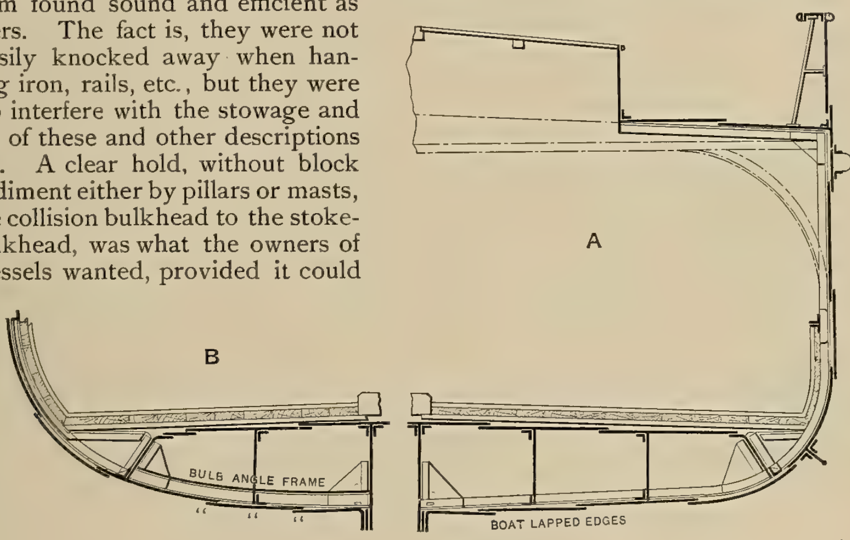


FIG. 12. FRAMING DETAILS.

The accumulated experience of year after year in the working of modern British coasting steamers has resulted in the close adaptation of every item in their hull and outfit to the purpose to be served. Finality of development has, probably, not yet been reached, but the present stage of evolution is highly creditable to those who have been principally concerned in its attainment.

FORESIGHT IN ELECTRICAL ENGINEERING.

By J. E. Woodbridge.

THE electrical engineer of the present time must avoid conservatism. If, in installing new work, he decides to adopt nothing that has not been tried and proven by the test of time, he is certain to regret that decision later. A plant, thoroughly up to date at the time of its construction, is so likely to be handicapped in a few years' time by rival installations using more modern methods and machines, that efforts should always be made to have everything, not only right up to date, but even ahead of date, if possible.

In the rapid growth of electric lighting, in the United States at least, some things have been so far quite largely overlooked. The chief of these is durability and long life of the plants constructed. One reason for this, and a good one, is that it is evidently poor practice to install expensive machinery, capable of long service, when new methods may, in a few years, necessitate its removal to the scrap heap. That reason, while specious in the past, has no longer any serious value, as methods and machinery have now become so well standardised as to render any apparatus, which is now the best, at least reasonably good during its life in service.

The chief reason for this false economy in American practice is that many plants are built either to sell, or to obtain franchises for speculative purposes. The demand for lighting is often very small when companies in the smaller cities and villages are started, and the companies themselves are poor. They order whatever apparatus they can get most cheaply and quickly, and decide to let the future look out for itself. A saw-mill engine and boiler is obtained and an arc light dynamo is belted to an overhead countershaft which is itself belted to the engine. After a time there is a prospect of a profitable demand for incandescent lighting, and a small Edison three-wire outfit perhaps is added. Later, there follows a demand for current for scattered residences, calling for the installation of an alternating current machine. Finally comes a call for power, perhaps for street railway use, and a 500-volt generator is added to supply that need.

The travelling men of the different boiler, engine, and electrical manufacturing and supply houses exercise all the beguiling blandishments known to sales agents, on the officers and engineer of the little company, with the result that the latter generally distributes its orders around so as to grieve no one and keep things moving.

The result in the stations must be seen to be appreciated. A miscellaneous collection of dynamos, of various makes, styles, sizes, epochs, and speeds, is belted to countershafts, and thence to engines with an equal lack of similarity. The boiler room exhibits a similar heterogeneity. The machines are run independently, requiring, in general, a separate distributing circuit for each dynamo.

It is impossible to find a similar case in other and more settled industries, but an assumed case in a familiar business will illustrate this fault. Suppose a water supply corporation should start in business in a small town. The first need for water would be for fire protection,

and that would be readily supplied by a pump forcing ordinary river water into a system of pipes connected to hydrants. Drinking water might be supplied by another pump and set of pipes, supplied from a lake or spring. Power distribution, for elevators, for example, could be provided from a third pump and set of pipes under high pressure. A fourth might supply pure water under high pressure for a high-level service.

Let us suppose also that, as the business increases, new pumps are added, of different styles, makes, sizes, and designed for different speeds. Suppose these to be power pumps, belted to a variety of engines, Corliss, high-speed, vertical and horizontal, compound and simple, condensing and non-condensing. Let a separate set of distribution pipes be run through the town for each pump. Add also a miscellaneous battery of boilers, cylindrical and water-tubular, locomotive and vertical. The whole presents a fair analogy to the majority of electric lighting stations in the United States. It takes no great acuteness to see that, at a fair price for water, such a water plant would find it difficult to pay dividends; and yet people wonder why it is that some electric light plants do not pay. The case is really worse with the electric plant than with the other, because small and cheap dynamos require more attendance, repairs and tinkering, depreciate faster, and break down more often than do small and cheap pumps.

Almost the opposite extreme is reached in European practice, where every effort is made to attain the greatest possible simplicity, durability, and reliability, regardless of first cost. Especially is this the case in Germany. The reasons for this comparatively greater foresight are various. European cities are already of established size, or are growing at a slow rate which can be definitely foretold. The proverbial slowness of the European,—from an American standpoint,—in establishing new enterprises prevents the construction of lighting plants until the demand to be supplied is known definitely, and prevents the rushing in of rivals where there is business sufficient for only one. The earlier and more popular use of the Welsbach incandescent gas burner, combined with the low price of gas in Europe, has caused a sharper competition there between gas and electricity, and necessitated a more rigid economy in the production of the latter.

There is also a greater proportion of municipal lighting systems in Germany than in America, and in all these plants, of course, the tendency for the best, as opposed to the cheapest, is greater than under private ownership. Then, those municipalities not owning their own plants, have been so stringent in their franchise limitations as to prevent the establishment of any wildcat or speculatively inclined companies, or any, in fact, but those with the most substantial backing and serious intentions.

The franchise of the Berlin Electric Works Company is a good example. The company is required to pay 10 per cent. of its gross receipts as rental for the use of streets for its conduits; also one-quarter of its net profit over and above 6 per cent. The rates allowed for street lighting are very low as compared with American standards, and its maximum allowable rates for private lighting are specified. The company is required to keep on deposit with the city a renewal fund in bonds equal to one-fifth of its invested capital; also a sum of about £10,000 as surety for the provisions of the franchise. Strict rules are also made regarding the tearing up of streets.

The difference in the nature of investors in America and Europe is also a prominent factor. While the investment in the United States is generally speculative, calling for quick and large returns, the demand in Europe is for a safe investment, which shall pay a small interest continuously for many years. The result is that before ground is broken for a European plant, the whole system is laid out with due allowances for everything that can be foreseen in the next quarter century. The best engineering talent available is employed, and all the possible alternatives in plans

and details are thoroughly discussed. First cost is not considered if running expenses or depreciation can be reduced in any way. Any increase in capitalisation that will effect a saving sufficient to pay 5 per cent. or even less on that increase is immediately undertaken.

The æsthetic tastes of the people are gratified by the correct architecture and decorations of the station buildings. Notice in this connection the handsome buildings of the International Electric Company at Vienna, and the turbine station at Tivoli, in Italy, built to match some old ruins in the neighbourhood. Inside, in spacious and well-lighted engine rooms, are placed massive, slow-speed, multiple-expansion engines of the most approved type on the market at the time of construction. The units are as large generally as the minimum load will allow, sometimes only two to a station. The dynamos, generally of only one type, size or make, are direct-connected to the engine shaft, one dynamo to an engine, as a general rule. The dynamos are designed for parallel running, allowing the whole load to be carried by one set of mains. These are put underground and are designed to last indefinitely. Experience is as yet too short to determine the rate of depreciation of these mains. Arc lights, incandescent lights and motors are designed for the one kind of current, and are all supplied by the same set of distributing wires.

Great pains are taken to keep up the efficiency of the distributing system. Where the alternating current system is used, the transformation to low voltage is made, not in a great number of small transformers of low efficiency in the buildings supplied, but in transformer stations erected or excavated at the street corners and feeding a set of secondary conductors. This permits the use of much larger and more efficient transformers, and reduces greatly the total transformer capacity needed, due to the fact that when three or more services are grouped together, the maximum loads of all are not likely to occur simultaneously. This permits the use of one transformer, supplying many customers, and being much smaller than the equivalent of the smaller transformers which would be needed with local transformation for the same customers. The transformer as used in America is a source of great loss.

There is now no question of the successful running of arc and incandescent lights and motors on the same wires and over large areas, either by the use of the direct-current five-wire, or the multiphase alternating current systems. Although alternating arc lights appear to have a lower efficiency than direct-current arcs, that disadvantage is balanced by the increased economy of large alternators over groups of small, inefficient, series arc machines, such as are largely used at present. The diminished complexity of such a combined system is a clear gain.

It is more than likely that this irrevocable determination of methods and systems will cause a conservatism in Europe which will prevent as rapid advances there in the future as in America. For the present, however, Americans have more to copy than to be copied, and deserve the joking criticism of an English engineer who is reported to have said that the most conspicuous feature of American electrical engineering practice was leather.

Although in the Eastern part of the United States rapid strides have been made towards a better practice, Western practice is still following all too literally the biblical admonition, which was certainly not intended to apply to electric lighting,—"Take, therefore, no thought for the morrow, for the morrow shall take thought for the things of itself."

ELECTRIC POWER AT HIGH ALTITUDES.

By Aaron B. Blainey.

A VIEW OF TELLURIDE, COLORADO.

NESTLING in a beautiful park on the western slope of the famous American Rocky Mountains, about four hundred miles southwest of Denver, in the State of Colorado, is the busy mining town of Telluride. Snow capped mountains look down upon it, and the San Miguel river, a beautiful mountain stream of considerable volume, flows within its confines. The town is the centre of a wealthy mineral region, and has an altitude of 8700 feet. The physical features that characterise all mountain localities are seen here in all their native ruggedness and grandeur. Forbidding mountains, wild gorges, yawning chasms, sparkling waterfalls, streams, like molten silver, dashing down the mountains, beautiful lakes, gems of the eternal hills, abound in the region.

But a few years ago this country was uninhabited save by the wandering Indian and the most daring prospector. The native saw nothing in the scenic grandeur around him, except as it appealed to his animal desires. The precipitous mountain sides were the homes of the animals whose carcasses furnished him food and clothing; the placid lakes and mountain torrents were fruitful in fish and wild fowl; that was all. The

THE POWER HOUSE AND BUILDINGS FOR THE OPERATING FORCE.

early prospector viewed them much in the same light; or, his eager thirst for gold overshadowed every other feeling.

Following close upon the heels of the aborigine and the early pioneer, however, there came an enterprising spirit who saw in the perpetual snows, the numerous lakes, streams and waterfalls the source of sufficient power, if it could be utilised, to operate any and all the industries that might follow as the country developed. To apply this power was the problem to be solved. The only demand for power was in connection with the mining industry, but the mines in most cases were too far removed from water power to make it available, except by the intervention of some agency other than mechanical.

Electricity was then comparatively in its early stages. Some use had been made of it in a commercial way for the transmission of power, but there was a limit to the distance at which it could be used to advantage. Direct current only had been used, and on account of the enormous losses involved when distance was encountered, its use was out of the question. The value of alternating curents in the transmission of electricity for lighting purposes had been demonstrated, but their value in the direction of power had not been proven as no motors of that class had yet been constructed.

With a comprehensive grasp of physical law Mr. L. L. Nunn, then largely interested in a number of mining and milling propositions at points where the excessive cost of fuel made the use of steam for power prohibitive, investigated the matter and as the result of his investigations the Westinghouse Company, of Pittsburgh, perfected and built the apparatus at Telluride, which proved beyond all controversy the value of the alternating current as a power transmitting agent. Thus it was that here, upon the frontier, where civilisation fades into savagery, with no facilities for delicate mechanical work, was rocked the cradle of power transmission by the alternating current.

Scarcely had the mocassin tracks of

the Indians been obliterated when there was begun an experiment, whose importance can be estimated only by the magnitude of its results. About eight miles south of Telluride, at the confluence of Howard and Lake forks, of the San Miguel river, a power plant was erected, and the Gold King milling plant, about three miles distant, was put in successful operation. Single-phase synchronous motors were used and so excellent was the service rendered that the power lines were extended until all the important industries within a radius of fifteen miles were operated from the same plant and by the same system.

During the following few years great advances were made in electrical science and apparatus. The more flexible multiphase machinery was made a commercial success and was coming into general use. Keeping pace with the times Mr. Nunn had the single-phase plant replaced in the spring of 1896 by an entirely new multiphase plant. This system combined the advantages of having generators and motors operated at a low electromotive force, with all the benefits of high-tension three-phase transmission.

Power is furnished by the waters of Howard and Lake forks, delivered through steel pipes to Pelton water wheels, at heads of six hundred and nine hundred feet respectively. A constant supply of water is insured by an extensive system of natural reservoirs which have been artificially improved. The largest of these is Trout lake, which covers about two hundred acres.

The generating plant consists of two two-phase generators, direct connected to the water wheel shaft. These generators are of 1000 horse-power capacity each and deliver a two-phase current at 500 volts to banks of step-up transformers, which, in turn, deliver it to the line at a pressure of 10,000 volts, three-phase, for transmission. At the receiving end of the line are banks step-down transformers which reduce the pressure to 220 volts for motor, and 110 volts for lighting, service. Each generator acts independently of the other, but switches are arranged, so that they can be readily thrown in parallel at will. The machines have twenty-two poles and run at a speed of 327 revolutions, giving a frequency of 7200. The transformers are in units of 100 kilowatts.

Leaving the power house, the line climbs the steep and rugged face of the mountain in the direction of Telluride. At a distance of two and a half miles, a branch line leaves in a southerly direc-

TROUT LAKE, ONE OF THE SOURCES OF WATER SUPPLY FOR THE TELLURIDE PLANT.

tion to the Gold King mine and mill, 3000 feet higher than the generating station. A 100 horse-power motor plant operates the mill and a 3000-foot surface tram for transporting the ore from the mine to the mill. Current is taken into the mine through an unused tunnel at the normal line pressure on bare copper wires. Two thousand feet from the surface a pair of transformers are installed and current is furnished for lighting the mine and operating a thirty horse-power hoist. A triplex pump, half a mile from the mill, operated by an electric motor, furnishes the mill with water during the winter months.

One mile further, on the main line, another branch circuit is taken to the Turkey Creek mill, owned and operated by the power company. Continuing, the main line crosses another range and drops into what is known as Prospect Basin, where another mill, also belonging to the same company, taps the line. After spanning a number of ravines and gulches and when it has reached an altitude of 11,000 feet it suddenly dips at a sharp angle into the town of Telluride. Here about 200 horse-power is consumed in light, heat and power. Another branch line leaves at this point, running two miles in a southerly direction to the largest ore milling plant in Colorado. This mill is equipped with a 250 horse-power motor and a large number of arc and incandescent lights.

From Telluride the main line follows the valley of the San Miguel for a mile and a half to the town of Pandora, the terminus of railroad transportation. The large concentrating works of the Smuggler Union Mining and Milling Company are located there, consuming about 150 horse-power. Here the valley terminates abruptly in a perpendicular semicircular wall of solid rock. But the power line does not stop; it enters the tortuous gorge of Marshall Creek and penetrates a country full of difficulties and danger. Snow slides hover on every slope, and it was only by adopting the most heroic measures that it was

SAN MIGUEL PARK AND MOUNTAINS, CROSSED BY THE POWER LINES.

ANOTHER VIEW OF THE COUNTRY PASSED OVER BY THE LINES.

possible to insure the safety of the line. It leaps from cliff to crag, spanning gulches and ravines, a thousand feet and more, to escape the path of the all-destroying snow slide.

At an altitude of 11,000 feet the property of the Confidence Mining Company is reached, where seventy-five horse-power is consumed in crushing and milling ore. This is also the distributing station for lights for the town of Smuggler and the Smuggler mine. Thousands of feet of tunnel and stope are lighted by incandescent lamps, and work underground is carried on with the same facility as on the surface.

Still loaded with energy the power line climbs further still. The Columbia Menona mine and mill are reached at an altitude of 12,500 feet. This property is equipped with the most modern machinery for mining and milling ore, including air compressors, hoists, air drills, trams, crushers and concentrators. All these are driven by two-phase motors, supplied with current from this system. The total energy consumed in lights and power is about 140 horse-power. Directly across the gulch, and almost within stone's throw, is the Japan mine, the property of the Mikado Mining and Milling Company. An extensive concentrating plant in connection with this mine is operated with electric motors.

Higher yet and almost at the summit of the range the Tom Boy property is reached. This mine has one of the most complete milling plants in Colorado, and is operated and lighted throughout on the surface and underground by electricity. A pumping station at a small lake on the opposite side of a range 14,000 feet high, supplies the mill with water during about four months of the year.

All these different industries, separated as they are by the most broken country, are operated with the same degree of certainty as if the motive power were a part of each individual enterprise. Light shines for the toiling miner with the constancy of a never-setting sun. Day and night, week in and week out, the wheels turn incessantly, moved by the silent agent which penetrates the gulches and gorges of this rugged country, like a sentient spirit, defying alike the lofty mountain ranges, the winter storms and summer lightnings.

With the early synchronous plant a degree of success was attained that was almost phenomenal. Power for a large number of industries, and excellent light service for the town of Telluride, were

THE GOLD KING ELECTRIC MILLING PLANT.

obtained from one generator and one transmission circuit. At the same time a very flexible arrangement for different classes of work was obtained by the introduction of direct-current generators driven by synchronous motors. These generators suitably located, furnished current to motors for operating hoists, pumps and other apparatus which called for intermittent power. In this way the single-phase synchronous system served an important purpose. It effectually bridged the gap that existed between early direct-current transmission and the multiphase long-distance work of to-day.

The electrical machinery for both plants was built by the Westinghouse Electric and Manufacturing Company, and its successful operation when subjected to the most crucial test, speaks volumes for the general excellence of that apparatus. Special mention is due to the non-arcing metal lightning arrester, the invention of Mr. Alexander J. Wurts. Without its protection operations would have to be practically suspended in those sections during the season when electric storms are extremely violent.

The entire electrical work was carried out under the general direction of Mr. P. N. Nunn, brother of the promoter of the enterprise. Associated with him have been a corps of assistants, young in years as well as electrical work, but who, by their close acquaintance with the hardships incident to this class of work in a country where almost everything must be done at a disadvantage, have gained a valuable practical experience.

The Telluride plant has a number of features, peculiarly its own. It is unique in having begun in the infancy of alternating current operations, and in having kept pace with all the improvements of the times. It stands alone in point of the number and variety of obstacles which it has overcome. Its lines have been constructed across the most broken and difficult country, endangered by snow slides in winter, and exposed to the most violent electric storms in summer. Many miles of line cannot be inspected for months, except at the risk of human life. It is operating apparatus and distributing lights at a greater altitude than any other plant in the world. It has invaded a territory where the excessive cost of fuel has made the use of electric power extremely beneficial, and has given an impetus to industries that, without its assistance, could not possibly

have survived. It has nursed to life and prominence enterprises that would otherwise have lain dormant indefinitely. Illustrative of this is the world-famed Tom Boy mine, now valued at millions, but which, a few years ago, went begging for an owner because the cost of operating left nothing for the operator. No other company has placed electrical machinery in a country where such primitive methods of transportation must be resorted to; even the wagon road is absent in many places; the pack animal takes what it can, and the heavier pieces arrive at their destination somehow. Suffice it to say, the engineer of other places would not always approve nor admire the method.

To construct complicated apparatus in a well-equipped manufacturing establishment is one thing; to place it in perfect running order on the almost inaccessible summits of the Rocky Mountains is quite another. The handling of heavy machinery in shops, with cranes and derricks, on railroads and paved streets, and the transporting of the same apparatus over dizzy mountain trails where the sure-footed mule can scarcely go with safety, takes engineers of special calibre, quality and attainments.

If the engineer who has never been outside the limits of civilisation wishes a contrast to his every-day problems, let him take a trip over the system of the Telluride Power Transmission Company's plant in the mountains of Colorado. When operations were first begun in Telluride, 3000 volts (the pressure then used) were considered a very high potential. Since that time a number of plants transmitting at 10,000 volts have been placed in operation. But the Telluride plant has not stopped where it began. While many prominent engineers have been theorising on the possibilities of high-tension transmission, the engineer corps of this plant have practically demonstrated its value. Power has been transmitted a considerable distance for commercial purposes at the enormous pressure of 60,000 volts. This work has been carried on in addition to regular work by way of experiment for the purpose of determining the tension limit in the practical transmisson of power.

SIR WILLIAM HENRY WHITE, K.C.B., L.L.D., F.R.S.

Assistant Controller and Director of Naval Construction of the British Navy.

AT the present day Sir William Henry White is a commanding figure in British service, with a fruitful past and the promise of years of splendid achievement yet to come.

Born at Devonport in 1845, he was apprenticed at the age of fourteen to Mr. James Peake, then master shipwright of the Royal Dockyard at that place. He continued there, learning the practical side of shipbuilding, until 1864, and at the same time his education was continued in the school attached to the dockyard. The British Admiralty now for fifty years have carried on this system of technical education, practical and theoretical training going on side by side. The results, although little known, are most remarkable. Men trained by the Admiralty not merely fill the highest places in their own service, but occupy similar positions in many of the private shipyards, and at Lloyds.

In 1864 the Admiralty, acting in conjunction with the Lords of the Council, established in London the Royal School of Naval Architecture, and threw open

to competition a number of scholarships. In this competition Sir William White took the first place, which he retained all through the course of three years, graduating in May, 1867, with a professional diploma as Fellow (first class) of the Royal School of Naval Architecture.

Mr. Reed, now Sir Edward Reed, was chief constructor of the navy at that date, and at once appointed the successful graduate a member of the constructive staff at the Admiralty. Sir William White has now served on that staff for thirty years with the exception of about two and one-half years mentioned below, and has risen through every grade, serving both in London in the dockyards and occasionally at sea.

From 1867 to 1870 he was employed as Sir Edward Reed's confidential assistant, and during that time was engaged, amongst other duties, in the preparation of various technical books and papers published by Sir Edward Reed. His assistance in these important professional works was suitably acknowledged, particularly in the standard book on "Shipbuilding in Iron and Steel," and in papers published in the Philosophical Transactions of the Royal Society.

Sir Edward Reed retired in 1870, and after an interval of about two years, during which the office of chief constructor was "in commission," Mr. (now Sir) Nathaniel Barnaby succeeded. During this interval the exhaustive inquiry took place into "Designs for Ships of War," ordered after the loss of the *Captain*. A strong committee, presided over by Lord Dufferin, was formed, and an immense amount of work had to be done in the form of calculations for strength and stability. This was chiefly done by the late Mr. W. John and Sir William White, under the direction of Sir Nathaniel Barnaby. Many new processes had to be devised, and the results were published by Messrs. White and John in the Transactions of the Institution of Naval Architects for 1871. This paper had a high practical value as well as much scientific merit and novelty, which were fully recognised by competent authorities. It was the first of a long series of contributions to the same Transactions by Sir William White, extending up to the present time.

In 1872 he was appointed secretary to the Council of Construction at the Admiralty and in 1875 assistant constructor. During the period from 1873 to 1877 he was largely engaged on detached duty at the dockyards, having to do with the construction of naval types then building, such as the *Devastation*, *Dreadnaught*, *Temeraire* and *Inflexible*. He also assisted Sir Nathaniel Barnaby in the investigations and experiments connected with the introduction of mild steel.

From 1878 to March, 1883, he was doing duty as one of Sir Nathaniel Barnaby's principal assistants in the Admiralty, and was formally promoted to be chief constructor in 1881. During this time he had charge of an important section of the design work, and assisted Sir Nathaniel Barnaby in the designs and construction of many important battle ships and cruisers, including the *Colossus*, *Impérieuse*, admiral classes of battle ships, as well as the *Leander* and *Mersey* classes of cruisers. He also drew up for Sir Houston Stewart, then controller of the British Navy, the scheme for the construction of a "Constructive Corps" for the Royal Navy, adopted in 1884 and still in operation.

In addition to his work at the Admiralty, Sir William White, from 1870 to 1881, undertook the duties of professor of naval architecture. For three years he served at his old school at South Kensington, and then organised the course of instruction at the Royal Naval College at Greenwich, where he served for eight years. Not merely were pupils, sent by the Admiralty or by private English firms, instructed there, but considerable numbers of foreign students were attracted. Many of these old pupils of Sir William White now hold the first positions on foreign navies, or in the shipbuilding profession at home.

Out of this work grew also the pub-

lication, in 1877, of the "Manual of Naval Architecture," which, in its revised form, still holds its place as a text-book, and has been translated into German, Italian, Russian and Spanish. It enjoys the rare distinction of being officially authorised for use by the admiralties of these countries, as well as the British. It is also used as a text-book in the United States Naval Academy.

Early in 1883 Sir William White decided to leave the Admiralty, and to take charge of the creation and development of the war shipbuilding department of Sir W. G. Armstrong, Mitchell & Co., Limited, at Newcastle-on-Tyne. It was an entirely new departure, as the yard had to be made from the beginning on a difficult site, and was designed to be capable of constructing and completing the largest classes of war ships. On leaving the Admiralty a special letter of thanks for past services to the navy was written by the Lords commissioners,—a somewhat unusual occurrence.

From April, 1883, to October, 1885, Sir William White remained in charge at Elswick. When he left, the new yard was in full working order, and a number of ships were on the slips, including the ill-fated *Victoria*, the order to build which to an Admiralty design had been secured. In these two and one-half years orders for battle ships and cruisers had been obtained aggregating over 30,000 tons displacement and nearly 70,000 horse-power, about two-thirds being for foreign governments and from Sir William White's designs. Austria, Italy, Spain, China and Japan were amongst the countries served. In the last days of his work at Elswick the United States bought his designs from which the cruisers *Charleston* and *Baltimore* have since been constructed. Four of the ships then built fought at the famous battle of the Yalu in the recent war between China and Japan.

Sir Nathaniel Barnaby retired in consequence of ill health in 1885, and Lord George Hamilton, then first lord, invited Sir William White to succeed as director of Naval construction of the British Navy. This invitation was accepted, although it was notorious that in accepting it Sir William White suffered considerable on the financial side. No doubt the attraction of holding a position which is acknowledged to be the "blue ribbon" of naval architecture, and the desire to be of public service, influenced the decision.

On October 1, 1885, office was assumed, and under special conditions Lord Northbrook's programme of construction was only just commenced, and there were large arrears of incomplete work on previous new construction. A great public agitation for the increase of the navy was in progress. The estimates for new construction had been increased from about two and one quarter millions in 1884–85 to three and three-quarter millions in 1885–86. This great increase in expenditure involved enormous increase in the labour of the department. It was supposed to be exceptional, but has not proved to be so. From the Parliamentary Returns it appears that for about fourteen years previous to the date on which Sir William White took office the annual expenditure on new construction averaged a little over £1,600,000; but in the eleven and one-half years following, the corresponding average expenditure has been £4,400,000. Put in another way, the official figures show that about twenty-four millions sterling represented the expenditure for fourteen years prior to October, 1885, and about fifty millions sterling, since that time. The average expenditure for the last three financial years has been about £5,900,000, and in the year now ending it approaches £7,400,000.

Taking the same sources of information, it will be found that during the period he has held office 174 ships have been built for the British Navy from Sir William White's designs. They carry 1510 guns, have a displacement tonnage of 861,000 tons, an indicated horse-power exceeding 1,400,000, and represent an expenditure of about forty-five millions sterling, exclusive of armaments. The ships built from his designs for foreign navies, as previously mentioned, are twelve in number, carry-

about eighty guns, are of 32,000 tons displacement and have engines of 75,000 horse-power.

This record of work done and expenditure incurred on the designs prepared by an individual naval architect has not been approached, and arises from exceptional circumstances. Necessarily it has been associated with enormous responsibilities and very hard work, for the supervision of materials and construction as well as design has to be considered.

In 1886 Sir William White was appointed assistant controller of the British Navy, in addition to his office as director of naval construction. The controllership is held by a naval officer of high rank and proved ability for periods rarely exceeding five years. There have been four controllers, three engineers-in-chief, and three officers in charge of dockyards since October, 1885.

Sir William White is a Fellow of the Royal Societies of London and Edinburgh; an Honorary LL.D. of Glasgow University, and a member of various technical societies. He has served on the council of the Royal society, and is now vice-president of the Institution of Naval Architects; past president of the Institution of Marine Engineers; member of council of the Royal United Service Institution, and the Institutions of Civil and Mechanical Engineers; and honorary member of the Society of Engineers, the Institution of Engineers and Shipbuilders of Scotland, and the North East Coast Institution of Engineers and Shipbuilders. He is also this year master of the Ancient Shipwrights Company, of the City of London.

In 1891 he was created a Companion, and in 1895 a Knight Commander of the Order of the Bath by Her Majesty, the Queen. His Majesty, the King of Denmark, has conferred upon him the distinction of Knight Commander of the Order of Dannebrog.

Current Topics.

When the important part is considered which the manufacture and sale of heating appliances for buildings play in modern industry, it seems rather strange that the converse operation, *i. e.*, that of furnishing cooling apparatus, has not been more industriously developed. An important industry has been built up in the United States in the production of cooling drinks for hot weather consump-

tion, and surely the gains of the ice man have been made public enough to attract attention to similar enterprises; but artificial cooling for houses during the heated term is a luxury yet to come. That such artificial cooling would not be conducive to health, can hardly be urged when it is considered that the principal suggestions which have thus far been made in the idea have been intended for hospitals where the restoration of health has been the main object in view, and while the figures are not at hand, it seems more than probable that there are nearly as many lives lost from excessive heat in summer as are due to cold in winter.

THE question of expense of cooling is one which can hardly be discussed until after opportunity has been offered to test practical appliances in actual operation, but it would probably not cost more to keep a building cool in summer than to keep it warm in winter, and the first cost could, doubtless, be materially reduced by combining the flues and radiators of both heating and cooling systems in one plant. No one would dream of expecting to get good work out of mechanics in an unwarmed building in winter, and every one knows, too, how difficult it is to keep men up to the mark when the mercury is in the nineties. The loss occasioned by the compulsory stoppage of work on days of such excessive heat might go a long way toward paying for the installation of the necessary apparatus for keeping the temperature at a reasonable point.

OF the several aids to safe navigation which have been brought out within the past few years, the eophone is a very promising example. As defined by its makers, it is an apparatus designed to enable an observer to determine quickly, and with great accuracy, the direction of an object or station from which acoustic signals are transmitted. This is both brief and exact, and, coupled with the sketch of the device on this page, leaves little more to be told. The principal features of the instrument are two sound receivers or collectors, separated from each other by a vertical partition, and so placed that sound waves, striking the partition at any angle, will be directed into or against the receiver on that particular side. The receiver on the other side of the partition will, at the same time, be so protected by the latter that the sound waves cannot enter it. In order that the observer may readily determine which receiver is, at any given time, within the range of the signal and which in acoustic shadow, so to speak, the receivers are provided with separate conveyors, or tubes, through which the sounds are transmitted to the observer. By these he is enabled at once, and with certainty, to ascertain which reflecting surface is, for the time being, exposed to the direct action of the sound waves proceeding from the transmitting station. Having ascertained this fact, he moves the apparatus about its vertical axis until the opposite receiver is made responsive to the sound waves, thereby locating the transmitting station at a point between the two positions from which observation had been taken. By moving the apparatus back and forth and carefully noting the alternate response of the two receivers, the observer is enabled quickly to adjust the apparatus so that the sounds, transmitted from both receivers, will be equal, and, when this point has been determined, the

THE EOPHONE.

longitudinal axis of the partition will stand on the line drawn from the transmitting to the receiving station, thus fixing the direction or position, of the transmitting station, and enabling the navigator to approach or avoid it as may be desired. The whole outfit, it will be observed, is simplicity itself. As to its efficiency, it would seem from what experience has been had with it, that excellent results are obtainable, and a number of vessels, among them the United States battle ship *Indiana*, have it in regular service. It has been found that the wind whistling over the edges of the partition and the receivers, causes disturbing noises in the transmitting tubes, causing more or less interference with the detection of faint sounds. This difficulty has been removed by surrounding the sound receivers with a curtain of silk, drawn tightly over a frame, which practically excludes the wind from the instrument while it does not at all interfere with the transmission to the receivers of the sound desired.

In these days of promoters and prospectuses there are many schemes into which the question of the cost of a horse-power enters. In the minds of many persons the greatest, if not the only, element in the cost of steam power is the fuel consumed, and the tremendous saving which is anticipated from the use of culm or other cheap fuel, or the total annihilation of power cost which is expected to follow the substitution of water power for steam, is based largely upon this mistaken notion. A careful examination of numerous estimates of the cost of power in the United States, made by reliable authorities, shows that when all the inevitable expenses, such as attendance, lubrication, interest on plant, depreciation, etc., are taken into account, with coal at an average price of from $3.50 to $4.50 per ton, the item of fuel ranges from 45 to 60 per cent. of the total cost.

Keeping this in view it is not difficult to estimate proportional savings which result from the use of a cheaper fuel. If we assume that the fuel cost is 50 per cent. of the total, and we save one-half of it we are saving not more than about 25 per cent., and if the change involves any increased expense for handling or cleaning, the economy will be still smaller. The somewhat extravagant ideas about the superior economy of water over steam power, it must be remembered, had their origin at a time when the steam engine was a far more wasteful machine than it is at present, and at points where coal was most expensive. Where ample water power is available, with but moderate outlay for installation, and coal at the same time distant and costly, the natural source of power may still hold its own, but all the above elements should be considered if a fair comparison is to be made.

Various plans have been suggested at different times for the utilisation of the energy developed by the rise and fall of the tides, but the intermittent character of the power has usually prevented any satisfactory solution of the problem. There is, however, one instance in which tide power has been quite successfully applied in a very simple manner. Along the river front at Liverpool there is a tendency for the accumulation of silt against the dock walls, requiring occasional dredging for its removal. Instead of using scoop dredges, this mud is removed at different periods by the use of tide power in the following manner:—Along the base of the dock walls is laid a pipe, perforated with holes, directed outward, this pipe being connected with the interior of the dock system, and suitable valves being provided to permit or check the flow of water. When the tide is very low, and consequently the head of water measured from the surface in the docks is at its greatest, a sudden opening of the connection permits a rapid flushing action by the water escaping through the holes in the pipe at the base of the walls, scouring out the mud and driving it out into the river to be carried away. As

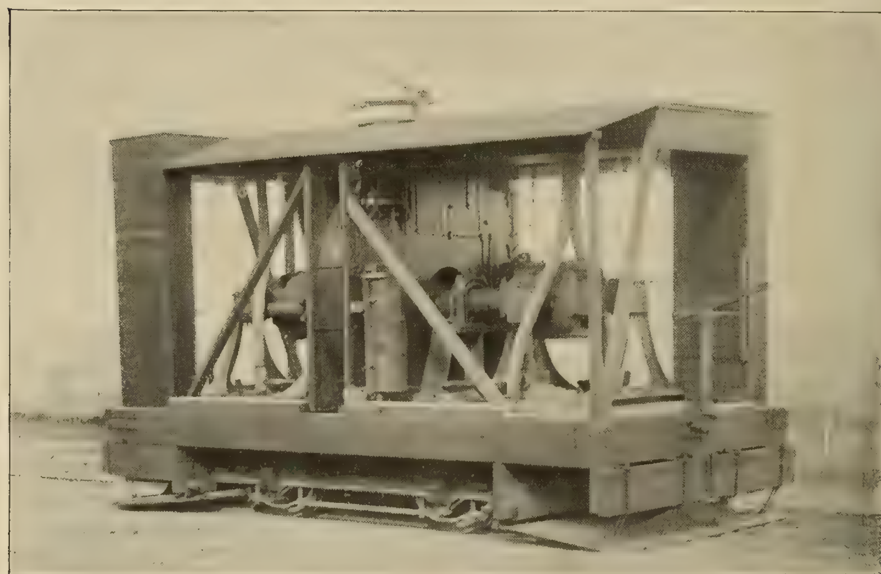
the tides at Liverpool average about twenty-five feet or more, it is evident that this simple form of dredging apparatus may be very effective, and as the times chosen for using it may be selected when the supply of water is greatest, it does not interfere with the regular use of the docks. Ultimately, no doubt, the introduction of practical and economical forms of power storage will render the equalisation of tide power commercially practicable, but at the present time, this example serves to demonstrate the fact that solar and lunar attraction, as expressed by the tides, have been harnessed in a small way at least.

OTHER natural sources of power have been only partially utilised and there are many, doubtless, which have even yet hardly been suggested. The energy stored in the coal beds has rightly been referred back to the sun and it is, no doubt, to the same source that we should ultimately attribute the heat developed at great depths below the surface of the earth. While it is believed that no practical attempts to utilise this subterranean heat have yet been carried into effect, there appears to be no good reason why the attempt should not be made, especially in volcanic regions, where quite high temperatures should be revealed at moderate depths. In a Colorado mining town an interesting combination was recently observed which a little ingenuity might have converted into a considerable source of power. Within twenty feet of each other were two springs, one of a temperature of nearly 200 degrees F., and the other not over 60, the flow of each being very uniform and the temperatures quite constant. The theoretical efficiency might readily be determined from the well-known law of thermodynamics, and the use of one stream to vaporise and the other to condense some volatile liquid, such as ammonia or bisulphide of carbon, might enable a fair percentage of the energy to be utilised which is now running to waste.

VISIBLE leakages do not have to exist a very long time before some attempt is made to correct them, especially when they involve corresponding financial dribblings; but sometimes the greatest leaks are altogether invisible and quite difficult to detect. Among such invisible leaks may be included those silent losses of power which occur in the transmission from engine to tool, or between the still wider extremes of furnace and wareroom. If it were possible to make each invisible, inaudible leak of power as apparent as a dripping faucet, or as perceptible as an escape of gas, there is not the slightest doubt that it would be instantly corrected, while, as it is, many proprietors persistently refuse to believe in the existence of such losses. It is not an uncommon experience for a series of tests to reveal that more than half of the total power developed in the engine room is absorbed in transmitting it to the point where the work is to be done. Great improvements have, doubtless, been made in power transmission by the substitution of small-sized high speed shafting, with swift belts or ropes for the old-time slow, heavy gearing, but there is still room for further improvement. Probably the purely mechanical lines of advance will lie in the direction of shorter lengths of shafting, as less likely to get out of line; the substitution of light, swift-running ropes, for wide heavy belts; and the reduction of journal friction by the use of lighter pulleys, and roller bearings.

AN electrically-driven pneumatic snow plow is an interesting part of the equipment of the Atlanta Consolidated Street Railway Company, of Atlanta, Ga. It was designed by Mr. Thomas Elliott, master mechanic of the line, and is peculiar in so far as the snow is blown from the track by an air blast instead of being removed simply by a conventional form of scraper or set of brooms. In this respect it is unlike anything that has previously been brought out in the snow plow line. As shown in the illustration on next page

the outfit comprises a fan blower, mounted on a heavy frame over a car truck, and delivering an air blast through overhead wooden boxes to the two ends of the plow. At each end there is what the designer terms a "shear," which is simply a steel plate, placed squarely across the track, and capable of being raised or lowered by means of a vertical screw at the end of the platform. In addition it is suspended on links so that it will swing backward and upward in case it strikes an obstruction, such as a guard rail or the pavement. The backward movement is resisted by springs which ordinarily hold the plate to its normal position, and at the same time serve to cushion the blow when an obstacle is struck at high speed. The snow is scraped from the roadway by the shear and is then blown out of the way by the air blast from the blower, which latter is driven by two 30 horse-power motors. Where the pavement is above the rail, the snow remaining on the rails is taken care of by adjustable steel scrapers that fit the rail, and is blown to one side by air delivered through the hose shown. Neither the snow removed nor that remaining is packed. Back of the rail scrapers and close to the wheels are the sand pipes. When passing teams on the road, the wind gate may be closed for an instant and the snow permitted to accumulate in front of the plow until the air is turned on again. The maximum depth of snow that the plow can handle has never been determined. It is adjusted in regular work to remove fifteen inches, though, with frequent running of a number of plows, that depth would not be likely to be encountered.



A PNEUMATIC SNOW PLOW.

THE revival of the agitation for the suppression of the smoke nuisance in many of the larger cities brings to attention the fact that smoke, in the common acceptance of the term, is probably the least objectionable constituent of the discharge from chimneys. The finely divided carbon is annoying mainly because of the ease with which the particles soil everything with which they come in contact, but it is the invisible outflow of furnace gases from chimneys which is mainly responsible for the deleterious effects upon public health.

Carbon, partially burned to poisonous carbonic oxide, sulphurous acid, ammoniacal vapours,—these are the objectionable products of the boiler furnace, and all of them are invisible and free from solid matter which might lead to their detection by the sense of sight. Mingled with the atmosphere they are not sufficiently evident by their irritating properties to cause popular complaint to the extent that is excited by clouds of black smoke, but at the same time the injurious effects upon health are none the less certain.

A very minute amount of carbon is sufficient to produce opaque clouds of smoke, as may be demonstrated by smoking a piece of glass until it totally obstructs the rays of the sun, and taking the weight of the glass before and after smoking it in a chemical balance. In fact, it has been estimated that the greatest weight of smoke that can be produced from a ton of bituminous coal is not more than twenty pounds. Any attempt to consume this would probably add mainly to the carbonic oxide emitted by the chimney and thus deliver it to the public in a more hurtful form than before. The true solution of the smoke problem is to burn the fuel, not in boiler furnaces surrounded by comparatively cool surfaces and every provocation to imperfect combustion, but in suitably designed gas producers. These would deliver to the heating furnaces a clean gaseous fuel, capable of being much more completely consumed, and emitting no smoke and far less deleterious gases of combustion.

It is a noteworthy fact that in the matter of transportation by water, quite apart from all questions of steam and electricity, it has been reserved for the present generation to make advances and improvements which apparently might have been made equally well a thousand years ago. Interesting reference to this was made some time ago by Sir Benjamin Baker in a presidential address to the British Institution of Civil Engineers. Thus, the aborigines of America and many races of mere savages early found out the advantage which the lightness of birch bark canoes gave them in war or in the pursuit of game, and paddles of all kinds were developed. Why, when speed was a matter of life or death to them, did they not ages ago give up paddles and take to oars, and find out, as our record-breaking rowing men have done, that, by the simple contrivance of sliding seats, an advantage is gained which, other things being equal, renders the result of a race a certainty? Again, why, when sailing ships had been in existence thousand of years, did Columbus set off to discover America in a carved and decorated seventy feet long sarcophagus which could neither sail nor weather a storm, instead of in a clipper ship?

The men who built the *Santa Maria* for Columbus, and many larger vessels, were quite capable as artificers of constructing, with the same materials and implements, clipper ships of 500 to 900 tons such as astonished the world in the historical race from China to London in 1866. At the end of May in that year, five vessels, the *Fiery Cross*, *Ariel*, *Taeping*, *Serica*, and *Taitsing*, left Foo-chow-foo, laden with tea, for the race home. With varying luck, the different vessels, at times covering 328 miles in a day, proceeded on their long course, and in the English Channel the *Ariel* and *Taeping* sighted each other for the first time since leaving China, and off Plymouth were racing neck and neck with every stretch of canvas set. Finally, after about a three months' race, the *Ariel* finished ten minutes ahead of the *Taeping*, having left China twenty minutes before her; the *Serica* arrived the same day, the *Fiery Cross* the following day, and the *Taitsing* the day after. Allowing for the difference of time in starting, three of the vessels did the passage in 99 days, and the two others took two days longer. Here

there was no help from steam or steel, but the old materials, wood and canvas, sufficed for the work. As so many advances might have been made in the direction of rapid transit by sea and by land by the skillful but illiterate mechanics of many centuries ago, without any aid from scientific research, it would appear probable that the reason for the solution of the problem being so long deferred was that wars, revolutions, and great social changes occupied men's thoughts in former times, and there was not that unceasing struggle for commercial supremacy and material advantages which is so characteristic of the present century. Necessity, therefore, did not give birth to invention.

A YEAR'S shipwrecks make the subject of an interesting compilation in a recent issue of *Engineering*, of London. It appears from this that during the past year 984 vessels of 708,459 tons were wrecked, lost or burned, or passed the narrow border from usefulness to decay. This is about an average result, although in 1895 there were 1237 vessels of 806,278 tons on the list; but then the average for several years was exceeded by 120,000 tons, so that this year's statistics are only a return to the former state. This is fairly satisfactory, for the total volume of shipping continues to increase, and thus the death rate is not so high. The ratio is only 3¼ per 100 tons owned. The last quarter of the year has been heaviest in its harvest of wrecks, the number being 327 and tonnage 202,676 tons, while the first quarter of the year naturally comes next with 282 vessels of 195,480 tons. The June quarter has only 164 vessels of 147,579 tons. The proportion of steamers to the total losses is rather larger than usual. As a rule, from 55 to 60 per cent. of the tonnage lost is of sailing ships; this year, however, less than one-half of the tonnage is of sailing ships—720 of 353,040 tons. Although the number of steamers lost is only 264, the tonnage is 355,419 tons, so that some large craft are included. In view of the wide ramifications of the British fleet, which equals that of all other nations combined, it is gratifying to note that the percentage of loss, is only 2.31 per 100 tons owned, while over the whole list the percentage is 3¼. Some of the European nations, it is true, have a ratio of less than this, but it should be remembered that the total includes 65,000 tons of vessels that have been broken up, or more than one-half of the total broken up in the world. Indeed, this equals one-fourth of the total British losses, and no other country attains such a low percentage of actual loss by misadventure as in the case of the British fleet. Norway's loss is equal to 5.96 per 100 tons owned; that of Italy, 4.32; Sweden, 3.7; Austria-Hungary, 3.44; United States of America, 3.10; Spain, 2.63; Holland, 2.6; Russia, 2.14; Denmark, 2.13; France, 1.86, and Germany, 1.35 per 100 tons owned.

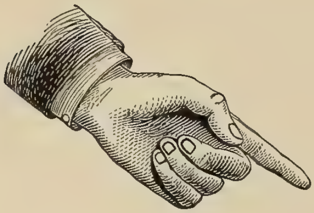
THE steam raiser's money that is wasted through the boiler chimney in the shape of excessive temperature and only partly burnt gases no doubt represents a goodly percentage of the coal bill totals, and the loss is probably tolerated simply because its full extent is not even vaguely suspected. A partial measure at least of the waste would be afforded by chimney gas analyses, but these are the exceptions, rather than the rule, even in places where refinements of many other kinds are in current use. Such analyses are not difficult to make, and would give valuable pointers to improved fire-room practice. One thing that they would show, indirectly, is that furnace fires are often carried much too heavy and that the air supply is inadequate to support proper combustion. With these conditions a boiler furnace becomes a very efficient form of gas producer, but does not exercise its proper function of liberating the greatest possible amount of heat from the coal fed into it.

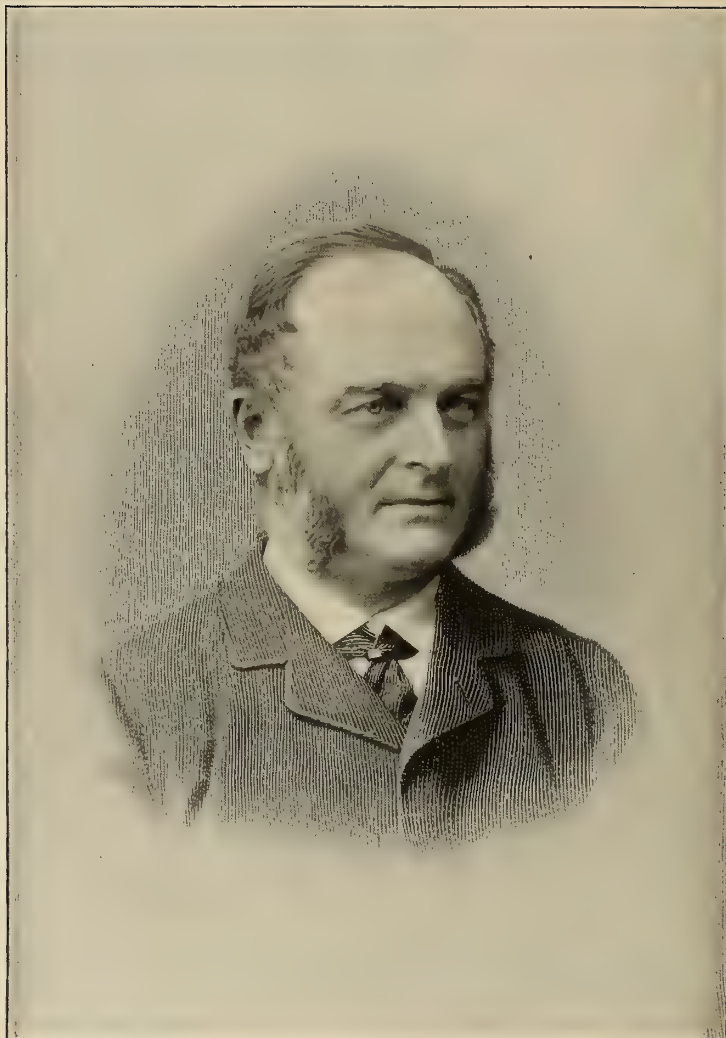
PRICE, 25 CENTS. $3.00 PER YEAR. PUBLISHED MONTHLY.

Cassier's Magazine—July, 1897.

CONTENTS.

$3.00 per year. 25 cents per number. Entered at the New York Post-Office as second-class matter.





PHOTOGRAPH BY G. G. LANGE.

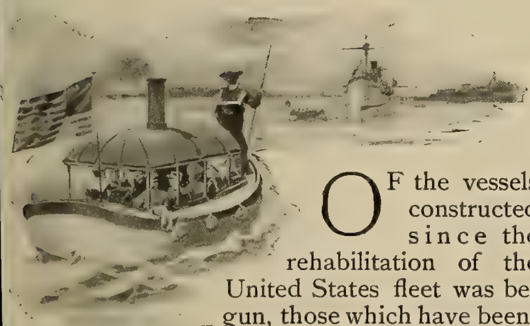
(See page 234.)

CASSIER'S MAGAZINE.

VOL. XII. JULY, 1897. No. 3.

SWIFT CRUISERS OF THE UNITED STATES NAVY.

By William Ledyard Cathcart.



OF the vessels constructed since the rehabilitation of the United States fleet was begun, those which have been, from their inception, most prominently before the public, both in America and Europe, are the commerce destroyers, *Columbia* and *Minneapolis*, which, while building, were known popularly as the *Pirate* and the *Corsair*, and which, hence, have become the prototypes of ships for the French Navy styled officially *Croiseurs Corsaires.*

The engineering problem, as to these ships, was difficult of solution. A hull of 7375 tons displacement was to be driven at a speed of 22 knots on an indicated horse-power of 21,000. With twin-screws this would have meant a thrust of 10,500 horse-power on a single shaft. While the United States Bureau of Steam Engineering had, from past experience, full confidence in the ability of the great works at Bethlehem, Pa., U. S. A.,—under the conduct of that eminent engineer, John Fritz—to produce steel forgings of the highest character, still, up to that date, no shafting for the transmission of this great power had been made in the United States. Again, a design including twin-screws would have necessitated not only massive shafting, for that day, but large parts of the machinery throughout, if with single engines of 10,500 horse-power on each shaft.

A further consideration was that of securing economy at moderate speed, when full speed was so high; and it seemed that this would be better attained by running engines of 7000 horse-power at, say, 2000, than those of 10,500 horse-power at a corresponding speed. The only further alternative was a twin-screw design with two engines of 5125 horse-power each on the same shaft—a method which involved much multiplication of parts, as well as disconnecting gear for one engine on each shaft, and special provision for the wearing down of the shaft bearings of the after engines.

The French experiments on the *Carpe* and the trials of the *Tripoli* had left no doubt as to the success of triple screws for those powers; and the French had shown their faith in them still further by the preliminary designs of the *Dupuy de Lôme*. In view of this and of the consideration above set forth, Commodore Melville, the engineer-in-chief

COPYRIGHTED BY A. LOEFFLER.

THE UNITED STATES TRIPLE-SCREW CRUISER "COLUMBIA," BUILT BY THE WM. CRAMP & SONS SHIP & ENGINE BUILDING COMPANY, PHILADELPHIA. TRIAL TRIP SPEED, 22.8 KNOTS WITH 18,509 I. H. P. DISPLACEMENT, 7350 TONS.

of the United States Navy, decided to apply triple screws to the commerce destroyers.

The results have shown the wisdom and skill of his design, since, in addition to the phenomenal speed of these ships at full power, they have, for ordinary cruising, a wide, economic range. Combinations are possible extending from the three engines at full speed to a single engine working, with fair economy, at less than half its power. The loss, in the latter case, due to dragging two disconnected propellers, has been shown, long since, by the experiments of ex-Engineer-in-Chief Isherwood, United States Navy, to be comparatively slight.

The *Minneapolis*,—on contract trial, the faster of the two ships,—is almost a counterpart of the *Columbia* in hull and engines, but has a slightly greater boiler power. The following is a brief descriptoin of her.—

General. — Protected cruiser with double bottom divided into 17 compartments. From stem to stern, and from 4 feet 6 inches below normal water line to 1 foot above it, a protective deck of nickel steel covers hull proper, being 2½ inches thick throughout with an additional thickness of 1½ inches on slopes over machinery spaces. A cofferdam, 5 feet wide and 7 feet 6 inches high, filled with compressed cellulose, extends the entire length of ship's sides and rests on protective deck. Forward, there is a steel conning tower, 5 inches thick. Length of boiler compartments, 136 feet; engine compartments, 76 feet; total length of machinery spaces, excluding shaft alleys, 212 feet. There are two main smoke pipes, instead of four, as on the *Columbia.* She will accommodate 27 officers and a crew of 417 men. Capacity of coal bunkers, 1518 tons.

Hull.—Length between perpendiculars, 411 feet 7¼ inches; length over all, 415 feet; beam extreme and on load water line, 58 feet 2¼ inches; midship section (immersed) area at normal draught, 1212 square feet; draught, mean, sea-going, normal, 24 feet; displacement, normal load draught, 8005 tons; number of water-tight compartments, below gun deck and including water bottom, 215.

Engines.—Vertical, inverted, direct-acting, triple expansion. Three engines, starboard, centre, and port, each with three cylinders. Diameters, 42 inches, 59 inches, and 92 inches; stroke, 42 inches.

Condensers.—Three main condensers (steam outside tubes), each with cooling surface of 9474 square feet. Two auxiliary Wheeler condensers, each with cooling surface of 680 square feet.

Air Pumps.—Three Blake, vertical, twin-cylinder main air pumps; two Knowles, horizontal auxiliary air pumps.

Pumps.—Six centrifugal circulating

THE THREE SCREWS OF THE "COLUMBIA."

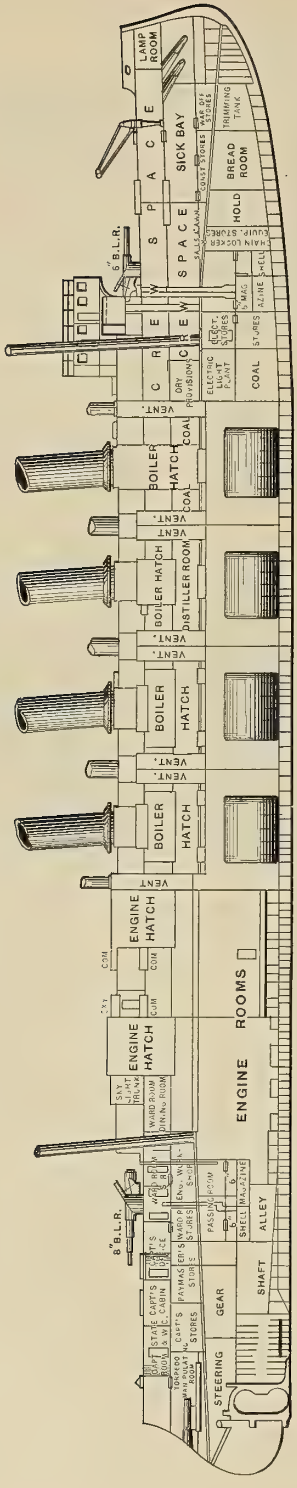
pumps, with a capacity of 6750 gallons per minute. Twenty-one Blake vertical, duplex pumps for fire, water, feed, and bilge services.

Blowers.—Sixteen 60-inch Sturtevant fan blowers for forced draft.

Screw Propellers.—Three, modified Griffith, manganese bronze propellers.

	Starboard and Port	Centre.
Diameter, feet	15	14
Pitch, " adjustable	19.5 to 22	19.5 to 22
" " as set	22	21.5
Disc area, square feet	176.71	153.94
Helicoidal area, " "	53.7	53.28
Centre of hub above lowest point of keel, feet	11.08	7.88
Immersion of tips of blades, least, feet	5.46	9.13

Boilers.—The main boilers are cylindrical, double ended; four furnaces at



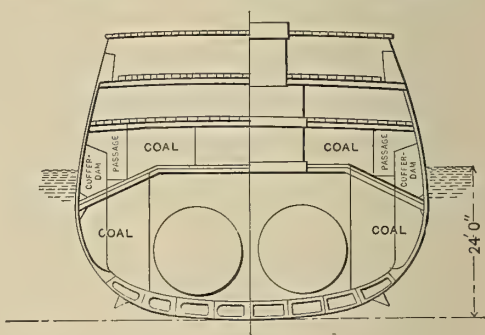
LONGITUDINAL SECTION OF THE UNITED STATES CRUISER "COLUMBIA."

each end. The two adjacent furnaces on each side of each end have a common combustion chamber. The auxiliary boilers are single-ended and have but two furnaces each. All furnaces are of corrugated steel.

Boilers.	Main.		Auxiliary.
Number	6	2	2
Diameter, external, feet	15.75	15.25	10.15
Length, " "	20	18	8.5
Working pressure, design, pounds	160	160	160
Grate surface, total, sq.ft.	1,120.2	336	64
Heating, "	38,405.3	9,789.2	1,952.64

Armament.—One 8-inch (40 calibre) rifle; two 6-inch (40 calibre) rifles; eight 4-inch rapid firing guns; twelve 6-pounder rapid firing guns; four Gatlings; four 1-pounder rapid firing guns; four torpedo tubes.

The *Minneapolis* made her official trial on July 14, 1894, this consisting in



MIDSHIP SECTION OF THE "COLUMBIA."

a run over a deep sea course, north from Cape Ann, Mass., to Cape Porpoise, Me., a distance of 43.968 knots; then a long turn at continued full speed, and a return trip over the course, the time actually on the latter alone being considered. The main data and results of this run were as follows:—

Draught, mean, 22.5 feet; displacement, 7387 tons; immersed midship section, 1126 square feet; coefficient of fineness, prismatic, 0.481.

	Starboard.	Centre.	Port.
I. H. P. each main engine	6,586.72	7,218.82	6,560.69
do. all do.		20,366.23	
do. all machinery, mean		20,862.30	
Speed per hour, knots		23.073	
Slip of propeller, mean, per cent	19.38	17.65	20 80
Indicated thrust (main engines only) per sq. ft. of developed area of propeller in pounds	1,394.4	1,573.3	1,378

THE UNITED STATES TRIPLE-SCREW CRUISER "MINNEAPOLIS." OFFICIAL TRIAL SPEED 23 KNOTS.
BUILT BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING COMPANY.

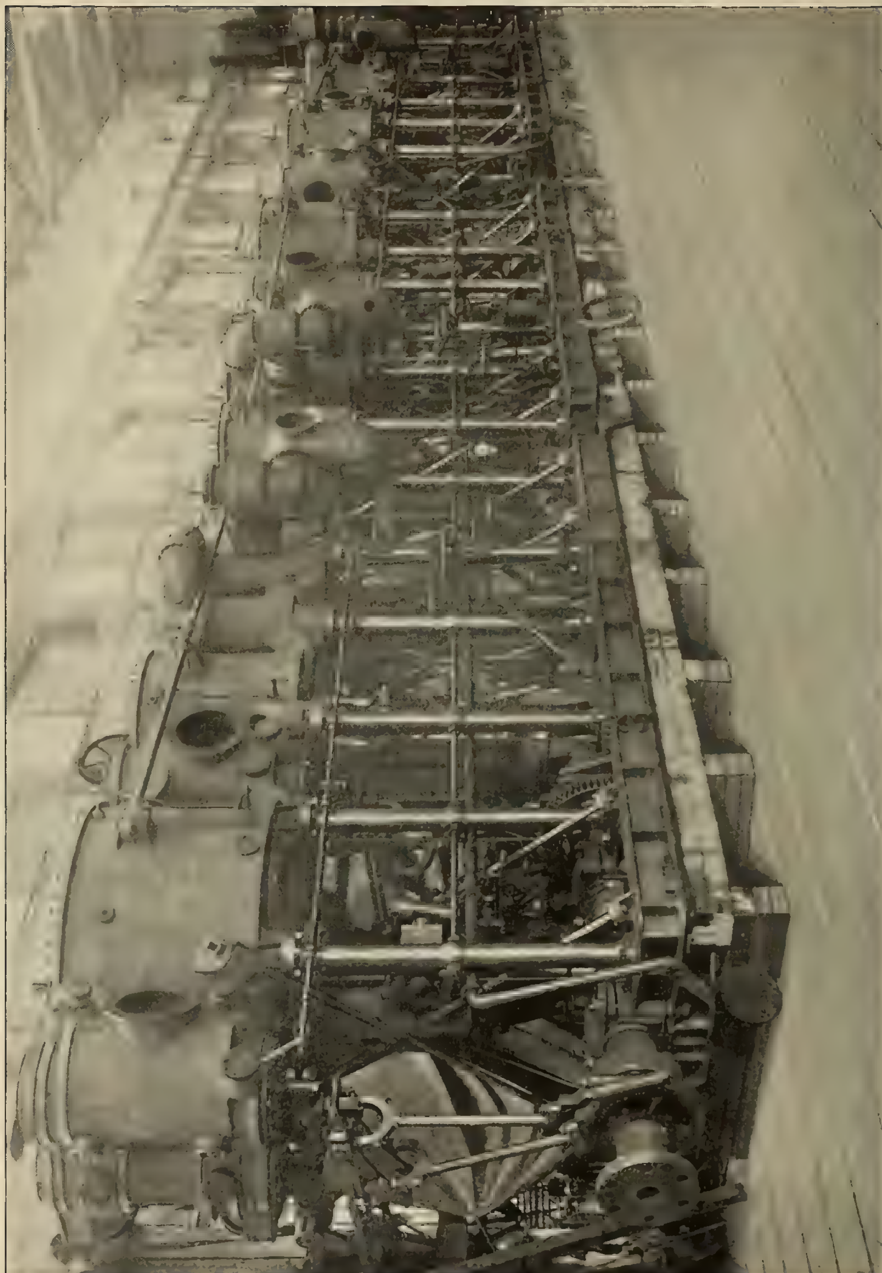
The results of this trial made the *Minneapolis* at that date the fastest large vessel in the world; and, for the length of the trial, the fastest vessel, large or small. The following comparison will here be of interest:—

	Minneapolis.	*Campania.*
Length between perps., feet	411.6	600
Beam, "	58.19	65
Draught, "	22.5	27
Displacement, tons	7,350	18,000
I. H. P	21,000	28,000

	Minneapolis.	*Campania.*
Speed	23	23
Coal in bunkers	1,700	4,000
Per cent. displacement in coal	23	22
Weight of machinery, tons	2,000	*3,000

* Approximate; less than actual.

It will be seen that, as compared with the great Atlantic liner, the cruiser is a remarkable vessel in point of speed and endurance on a comparatively small displacement.



THE ENGINES OF THE "MINNEAPOLIS." CYLINDERS 42, 59 AND 92 INCHES DIAMETER. STROKE, 42 INCHES. MAXIMUM I. H. P., 21,000.

There are on the *Minneapolis*, for all purposes, 94 engines with 180 steam cylinders. Her dimensions and power may be, perhaps, most adequately shown through the method of comparison used so ably by Sir Henry Bessemer as to the output of Bessemer steel. In discussing this ship, Professor Hollis, of Harvard University, has said:—

"Her low-pressure piston, which is 92 inches in diameter, has an area of 46 square feet, a very comfortable 6 feet by 8 feet stateroom on board ship, and this piston has an initial load of 100 tons, equal to the weight of three locomotives. The mean piston speed at maximum power will be 11 miles an hour, and the maximum speed 16 miles an hour. The tip of the propeller blades will move through the water at the moderate rate of 75 miles an hour. The condenser tubes, if placed end to end, would form a tube 33 miles long, and, if flattened out, would cover about two-thirds of an acre. The cooling water passed through these tubes will be equal to thirty-six millions of gallons per day, enough to supply a large city with water.

"The main boilers, if placed end to end, would form a tunnel 156 feet long and large enough for a train of cars to pass through. If divided up into rooms, they would supply a hotel with sixteen fair sized bedrooms. The heating surface is equal to one and one-eighth acres. The grate surface, if arranged on one grate, would equal one small town lot of 20 feet front and 77 feet depth. The boiler tubes, placed end to end, would be 13½ miles long. The blowers are capable of supplying 84,000,000 cubic feet of air an hour, which would supply a good sized yacht with a 10 knot breeze.

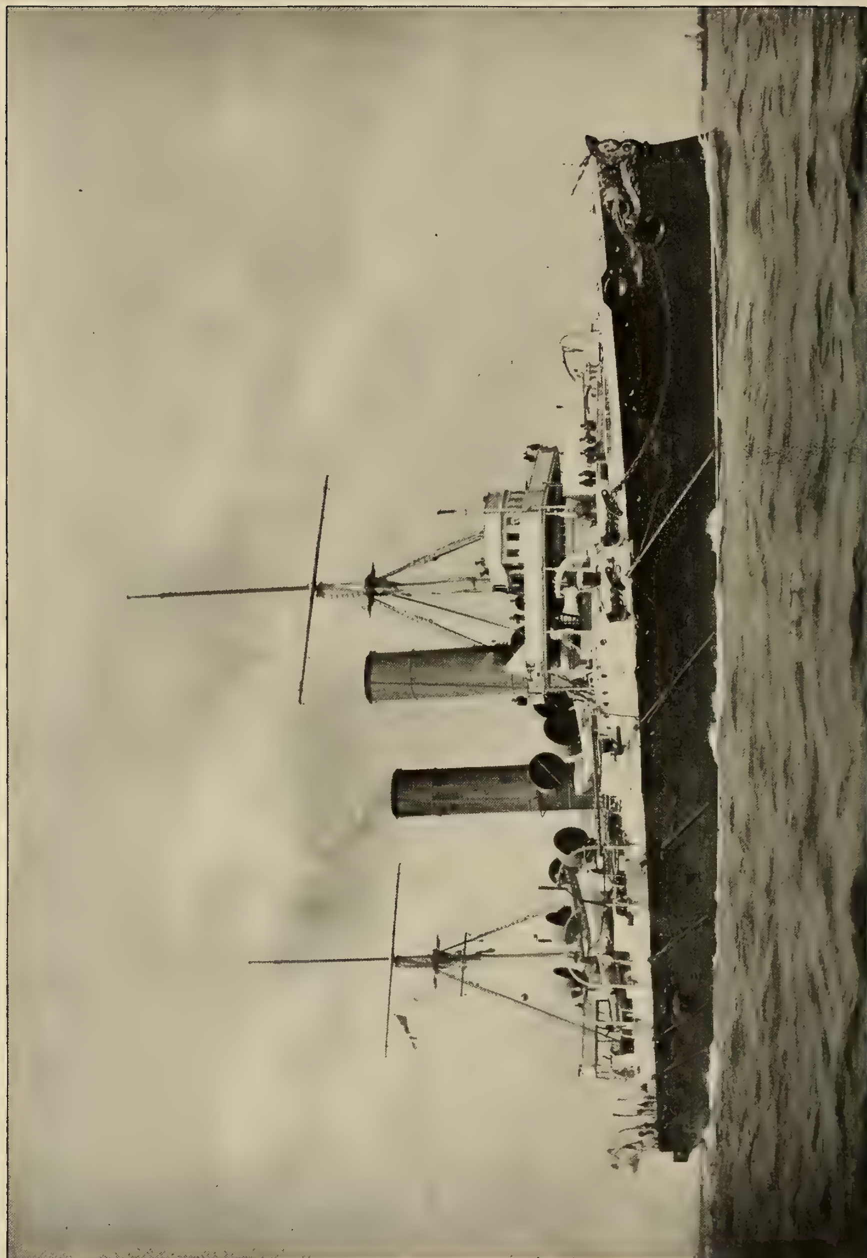
"The coal required for a full power run across the Atlantic would supply 150 families for one year in New York State. With 20,000 horse-power she would lift herself (7500 tons weight) to the Brooklyn Bridge in three minutes, if hoisting ropes were coiled around drums on the shafts. If the engines were set up on shore and used as a catapult, they would throw a 300-pound weight with such velocity that it would go off into space entirely clear of the earth's influence."

Her sister ship, the *Columbia*, attained, on her trial run, a speed of 22.8 knots on an I. H. P. of 18,509. That these great speeds could be well maintained, under the conditions of active service with naval crews, was demonstrated notably by the remarkable performance of the *Columbia* in her passage across the Atlantic in the summer of 1895. She left Southampton at 12.30 P. M. on Friday, July 26, passed the Needles at 2 P. M., and arrived at Sandy Hook at 8.59 A. M., on Friday, August 2, having made the run of 3090 miles in 6 days, 23 hours, and 49 minutes,—an average rate of 18.41 knots.

The conditions of the run differed appreciably from those of her acceptance trial. She was manned simply by her usual crew, not by trained premium winners from the ship yards. The entire run was made under natural, and not the forced, draft of her trial. When she left Southampton, she was down by the head, drawing 26 feet 3 inches forward and but 25 feet 6 inches aft, from which cause she, at times, shipped considerable water. And finally, the mean draft for the run was 24 feet 2¾ inches, corresponding to a displacement of about 8152 tons, while her trial displacement was but 7350 tons.

Under these conditions, the run of the *Columbia* must be considered a most remarkable one for a man-of-war. It proves that the vessels of this class are capable of maintaining, under natural draft, over long stretches of sea, a speed inferior only to that of a few of the ocean greyhounds. Up to that date, the best runs of the six fastest transatlantic steamers, over the same course, had ranged, in time, from the 6 days, 10 hours, and 32 minutes, of the *Fürst Bismarck* to the 6 days, 18 hours, and 47 minutes of the *St. Louis*, the *Columbia* being but five hours behind the latter. It will be noted that the mail steamers use forced draft and that their fire-room force is relatively greater than that of the *Columbia*.

A later vessel than the *Minneapolis*, which has shown qualities worthy of rec-



THE BRITISH TWIN-SCREW CRUISER "BLENHEIM." BUILT BY THE THAMES IRON WORKS & SHIPBUILDING CO., LTD., LONDON.
DISPLACEMENT, 9000 TONS. I. H. P., 21,411. SPEED, 21½ KNOTS.

ord, is the United States armoured twin screw cruiser *Brooklyn*, of 9270 tons; 18,769 indicated horse-power; 20 guns; and 21.91 knots,—a speed which places her, although a well armed and armoured vessel, almost, as to this, in the class of the commerce destroyers. The *Brooklyn*, while differing in many respects, is, in effect, an improved form of the *New York*, a powerful cruiser of the United States fleet, and resembles, to some extent, the *Blake* and *Blenheim* of the British Navy.

The following are the chief data regarding her:

Hull.—Length between perpendiculars, 400 feet 6 inches; length over all, 402 feet 7½ inches; beam, extreme and at load water line, 64 feet 8¼ inches; area of immersed midship section, 1367 square feet; draught, forward and aft, sea-going, 24 feet; displacement, sea-going, load draught, 9271 tons; number of water-tight compartments, 242.

There is a double bottom, 3 feet 6 inches deep amidships, divided into 13 water-tight compartments. There is a coffer-dam on each side 3 feet 6 inches wide, extending the whole length of the ship between the protective and berth decks, which dam is packed with cellulose. The top sides tumble home to give more fore-and-aft fire to guns in midship turrets. Capacity of coal bunkers, 1693 tons.

Armament. — Eight 8-inch guns, mounted in pairs in four turrets; twelve 5-inch rapid fire guns in sponsons on gun deck; twelve 6-pounders; four 1-pounders, and four machine guns on rails and in tops; four above water torpedo tubes, two on each side.

Armour.—A protective deck extending throughout ship, 3 inches thick over machinery space, and not less than 2½ inches elsewhere; glacis plates, 3 inches thick, around engine hatch; side armour, 3 inches thick, from 4 feet above to 4 feet below water line, for a length of about 192 feet opposite machinery space; exposed barbette armour of turrets, 8 inches thick, unexposed, 4 inches; turret armour 5½ inches thick; sponson armour, 4 inches thick; secondary battery protection, 2 inches thick; splinter bulkheads, 1½ inches thick; conning tower and shield, 7½ inches thick; armoured tube from conning tower, 12 inches internal diameter, and 5 inches thick. The side, turret, and barbette armour is of Harveyised nickel steel; the conning tower and shield are of forged steel.

Engines.—Four vertical, direct-acting, three-cylinder, triple expansion engines, two on each of two shafts, with disconnecting gear between each forward and after engine.

Cylinders, diameter, H. P., st'b'd, for'd, $31\frac{15}{16}$ ins., all others, $31\frac{31}{32}$ ins.

Cylinders, diameter, I. P., port, for'd, $46\frac{31}{32}$ ins., all others, $46\frac{15}{16}$ ins.

Cylinders, diameter, L. P., st'b'd, for'd, $71\frac{15}{16}$ ins., aft, 72 ins.

Cylinders, diameter, L. P., port, for'd, $71\frac{31}{32}$ ins., aft, $71\frac{15}{16}$ ins.

Stroke of pistons, 42 inches.

Condensers.—Four main condensers (steam outside tubes); cooling surface, one condenser, 5425 square feet. Two auxiliary (Wheeler) condensers; cooling surface, one condenser, 800 square feet.

Pumps.—Four main double, vertical, single-acting, Blake pumps, and two auxiliary pumps. Four main circulating centrifugal, double inlet pumps; simple, single cylinder engines, 12 inches diameter, 9 inches stroke; diameter of runner, 42 inches; of suction and discharge, 14 inches. In addition there are fifteen feed, fire, bilge, and water service pumps.

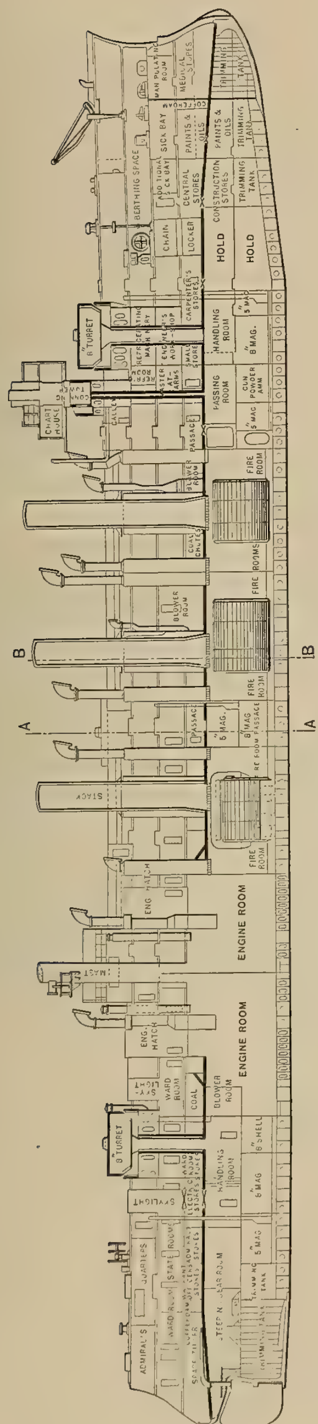
Screw Propellers.—Two, true screw, 3-bladed propellers, of manganese bronze; blades bent back and pitch adjustable from 19 feet 6 inches to 22 feet 3 inches; the starboard screw is right, the port, left-handed; diameter, 16 feet 6 inches; diameter of hub, 54 inches; helicoidal area, one screw, 75.74 square feet.

Boilers.—There are, in all, seven boilers, as given in the annexed table:—

	Double-ended.	Single-ended
Number	4—1	2
Length	18 ft.—19 ft. 11½ ins.	9 ft. 5 ins.
Diameter	16 ft. 3 ins.—16 ft. 3 ins.	16 ft. 3 ins.
Furnaces, number, total	32—8	8
Working pressure	160 lbs.—160 lbs.	160 lbs.
Grate surface, all boilers, total		1016.2 sq. ft.
Heating surface, all boilers, total		33,432 sq. ft.

Forced Draught.—Closed fireroom

THE UNITED STATES TWIN-SCREW ARMOURED CRUISER "BROOKLYN," BUILT BY THE WM. CRAMP & SONS SHIP & ENGINE BUILDING CO.
TRIAL TRIP SPEED, 21 KNOTS. DISPLACEMENT, 9271 TONS. MAXIMUM I. H. P., 16,000.



LONGITUDINAL SECTION OF THE "BROOKLYN."

system; 12 Sturtevant blowers, 60 inches in diameter, 18 inches wide.

General.—Weight of all machinery, including water, 1543 tons. For all purposes, there are on board this vessel 81 engines with a total of 156 steam cylinders.

Official Speed Trial.—August 27, 1896, data:—

Draught, mean, 21 feet 10½ inches; displacement, 8150 tons; immersed midship section, 1225 square feet; I. H. P., four main engines, 18,248.28; I. H. P. all machinery, 18,769.62; average speed, per hour, 21.9117 knots; slip, mean, of both propellers, 18.67 per cent.

The *Brooklyn* is the first war vessel of the United States, and perhaps of any other country, to be equipped with smoke pipes of great height in order to produce a strong draft and to obviate, in some degree, the use of blowing engines. Her pipes are 100 feet high from the level of the grates to the top.

Previous to her design, the merchant steamer *Scot* had been fitted with pipes 120 feet high by the Messrs. Denny, of Scotland. The practice was a somewhat radical departure for warships, but the engineer-in-chief of the United States fleet, recognising its advantages, advocated it strongly and successfully with the Secretary of the Navy in a memorandum, of which the following is a summary:—

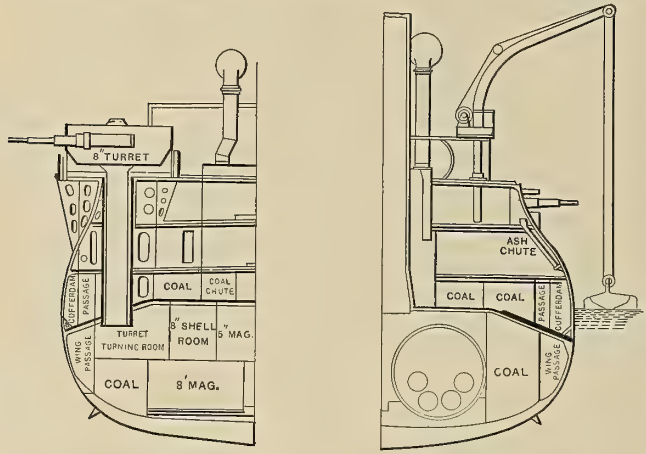
High smoke pipes give increase of speed without injury to any mechanism. An additional height of 40 feet will be equivalent to about one-half inch water pressure in draft with an increase in combustion of 10 pounds per square foot of grate.

Increased life of boilers will also result from the high pipes. All experience goes to show that long continued use of forced draft, by pressure in fireroom, has a deleterious effect of boilers.

Increased economy of combustion at moderate powers is another advantage of high smoke pipes. When one of the large boilers of the *Brooklyn* is under steam, it is estimated that there will be expended, in supplying loss by radia-

tion, from 2½ to 3½ tons of coal per day. Therefore, if, with a short pipe, it requires three boilers to make the desired speed; and if, owing to increased combustion, it would require but two with the large pipe, there would be a saving of from 2½ to 3½ tons per day.

The high pipe will produce also a



Section at *A A*. Section at *B B*.

CROSS SECTIONS OF THE "BROOKLYN."

further economy of combustion due to the more energetic combination of the oxygen of the air with the fuel,—an effect shown by repeated experiments with moderate forced draft. A still further economy is the saving of extra coal needed to run the blowers with the short pipe. This, with the eight large blowers of the *Brooklyn*, would be the amount necessary to produce from 50 to 75 horse-power, or, at a low estimate, 3 tons per day.

There is, too, a saving in repairs to blowers, whose wear is great, owing to the impossibility of protecting fully the working parts from dust; and a saving in labour, since the high pipe will give an increased combustion equivalent to one-half inch water pressure, without running blowers, which, when all are started, require the entire time of several men.

The *Brooklyn*, on her official trial, developed unprecedented speed for a ship of her type. In all other respects, also, that trial was most successful. There was allowed to the builders a premium of $50,000 for every quarter knot in excess of the contract speed, under which provision they received $350,000. It is evident, therefore, that all necessary effort was put forth to supply the engines with every pound of steam which they could work off; and yet, despite the further provision permitting an air pressure of 2½ inches to be carried in the fireroom, the average pressure recorded was but 2.26 inches, showing that, with the high pipes, steam could be produced in excess of the cruiser's maximum needs.

In confirmation of this, there appears, in the account of the trial, written by one of the officers who served on it, the following:—"The increase in the height of the smoke pipes relieved matters very much in the fireroom, the necessary steam pressure being maintained without running the air pressure up to the 2½-inch limit."

If Commodore Melville were to be credited with nothing further than the designs for the machinery of the three cruisers which have been described, his fame as an engineer would still rest secure; but, in the long roll of other ships which form the new United States fleet, one may look in vain for anything but success in that which has been attempted.

The *Columbia*, *Minneapolis*, and *Brooklyn* were built by the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa., U. S. A. The contract prices with the premiums paid for excess speed were as follows:—

Columbia	$2,725,000	$350,000
Minneapolis	2,690,000	414,600
Brooklyn	2,986,000	350,000

In view of the high qualities of the *Columbia* and *Minneapolis*, it seems remarkable to find their value decried by some United States naval critics. This

is chiefly due, perhaps, to the opinion, prevalent to some extent, that "the craze for speed is the vice of modern naval architecture," entailing too many sacrifices in other directions. Shortly after the first of these ships went into active service, an American officer of high rank gave it as his conclusion that "these high-speed commerce destroyers can as well be obtained from the merchant marine in time of war as from the navy; better, indeed, for the conditions are such that the merchant steamer is far more apt to be perfectly ready for work when wanted."

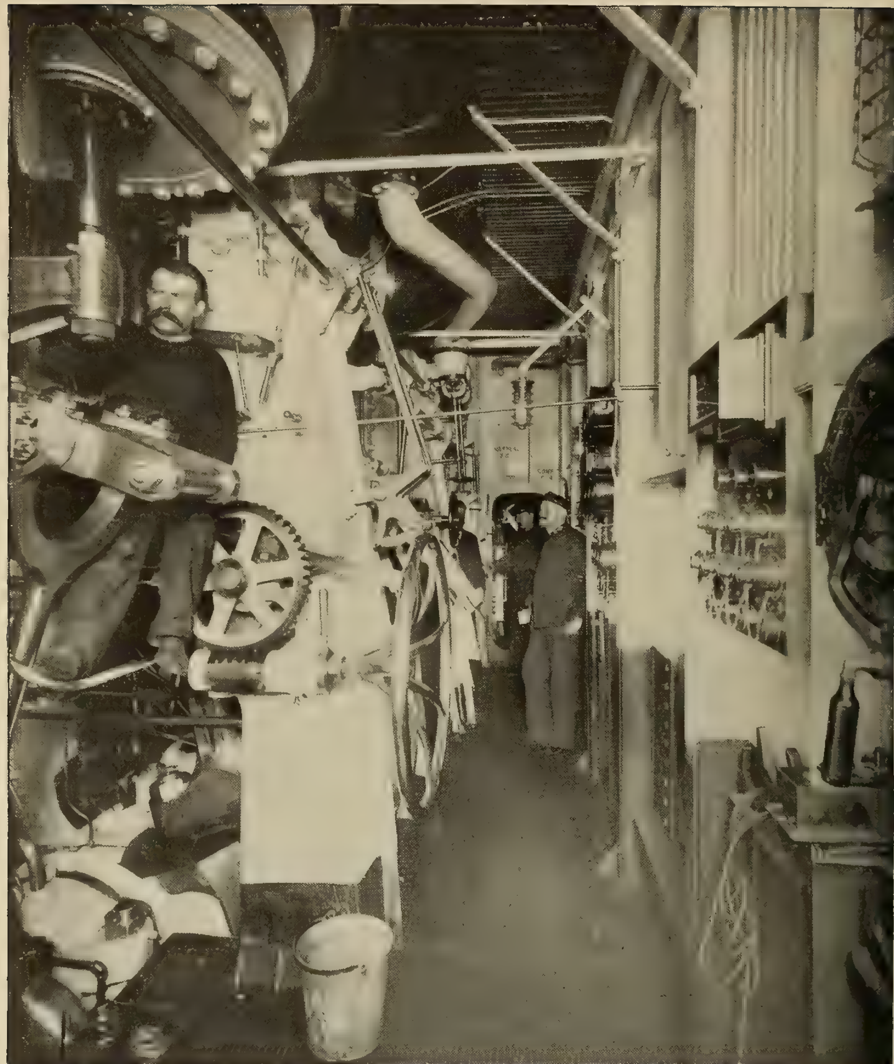
Later, another able United States officer elaborated this dictum thus:—"What protected cruisers we have built were educational, but we do not need any more (at this time, presumably). Gunboats serve all the purposes in times of peace. The building programme should now be battleships, coast defenders, armoured cruisers, torpedo boats, and armed merchant vessels for cruisers and scouts.

"The development of an improved *St. Louis* (International Navigation Company) type is now in order. Armoured protection to the engines and boilers should be provided at the expense of the government, making them really 'protected' cruisers. While vessels like the *Columbia* and *Minneapolis* are so expensive to keep up in time of peace, the merchant ship of the same type is paying dividends."

For nearly a score of years, the navy of the United States went slowly to decay. The American people, when the strife between the North and South had ended, were weary of war and turned eagerly to the arts of peace. The struggle for an adequate and modern fleet has been long and difficult. Against its advocates have been arrayed the lack of knowledge of many who, in distant inland homes, could not realise the hazard of the defenseless coast.

With others, more informed, there was a curious belief, whose base was national pride, that, in danger's sudden hour, naval *matériel* would, in some magic fashion, appear, full fledged, through the traditional "American ingenuity,"—a strange phrase, indeed, to conjure with in an era when a battleship requires years in building and a high

THE TWIN-SCREW STEAMER "SCOT," BUILT BY MESSRS. WM. DENNY & BROS., DUMBARTON, SCOTLAND. HEIGHT OF SMOKE-STACKS, MEASURED FROM LEVEL OF GRATE, 105 FEET.



IN THE ENGINE ROOM OF THE CRUISER "BROOKLYN."

powered gun, many months. And others, yet again, forgetful of the blood and treasure spent in the making and the guarding of the American Republic, were swayed by such Utopian and altruistic sentiments as are credited to the president of a leading university who is reported to have said:—

"The building of a navy and the presence of a large standing army mean the giving up entirely of the teachings of the early Republic. * * * The building of a navy, and particularly of battleships, is English and French policy; it should never be ours."

Not in this slumbrous fashion, shall there be guarded that liberty whose price, in all ages, has been blood and tears; that liberty which, for the Anglo-Saxon race, was born at Runnymede, cradled in Magna Charta, and wooed and won at Naseby and Marston Moor; that liberty whose firm hand sped "the shot heard round the world;" whose serene smile shone, in blessing, on the haggard troops at Valley Forge; whose

light footfall led the advance on many a trampled field, from the "stern and rock bound coast" to the swamps of Marion's men.

But all these,—the lack of knowledge, the indifference, the mere theories of the doctrinaire,—weigh but lightly in the scale against the calm and wise words of Washington, who bade that "early republic" to take "care always to keep ourselves, by suitable establishments, in a respectable defensive posture"—a "posture" which, in 1837, President Andrew Jackson defined, clearly and strongly, when he said:—

"Our local situation, our long line of seacoast, indented by numerous bays, with deep rivers opening into the interior, as well as our extended and still increasing commerce, point to the navy as our natural means of defence."

But, for a powerful fleet, the American nation has other reasons than defence alone. Mahan writes of "the not far distant day when the United States people must again betake themselves to the sea and to external action, as did their forefathers, alike in the old home and the new." Wearied by an exhausting war and absorbed in the development of the lands, the manufactures, and the markets of a continent, that people seems to have turned, for a generation, from nature's great highway, the sea. It seems to have forgotten the exceeding worth to it of maritime commerce, not alone in intrinsic profit, but, as well, in the ways of communication thus given a nation isolated geographically from the great body of civilised peoples. And, too, it has seemed unmindful of that principle which history so clearly proves, that sea-borne commerce and naval power must progress hand in hand. In sharp contrast with American indifference as to this, Mr. Charles H. Cramp has shown the ceaseless energy of Great Britain. He has said, in part:—

"England, clearly seeing, that, in this age more than ever before, ocean-empire is world-empire, strains every nerve to perpetuate her sea power. * * * Though in 1885, England already had a navy superior to those of any two, and equal to those of any three, other powers, if not to all others, she has, since that date, built a new navy, which, with what remains most available of the old one, overshadows the world. * * * Since 1885 England has expended five hundred and seventeen millions of dollars for new ships of war and their armament. * * * The aggregate (thus added) is 270 vessels of 1,156,575 tons total displacement, and 1,674,700 horse-power. * * * In personnel afloat she has augmented her force from 52,600 in 1885 to 100,500 in the estimate for 1897. In other words, England has doubled her navy in personnel and material and more than quadrupled it in war-like efficiency, during eleven years of the profoundest peace the world ever saw.

"Even greater exertions has England put forth in the augmentation of her merchant marine. During the calendar year 1896, she has added 1,380,000 tons of new steel steam shipping to her merchant fleet, breaking up meantime 530,000 tons of old and obsolete shipping which could no longer be operated profitably, a net addition of 850,000 tons to the total of her merchant marine by the register, but a practical addition of the whole 1,380,000 tons, because the 530,000 tons broken up had done its work for her aggrandisement and simply passed through the scrap heap and the mills into the new tonnage."

Such tremendous expansion as this, in naval and commercial strength, may well arouse the wonder of the world. In comparison with it, the utmost that can be said as to the United States is, that for it, in maritime power, the day-dawn seems, at last, to have come; that the ebb seems to have been passed and the flood to have set in with its relatively small, but wholly modern and efficient fleet. In this new movement, it may be safely assumed that the nation which, through its representatives, has authorised that fleet, will require, of the builders, ships that lack in no essential.

A ship-of-war is, in her design, but a combination of compromises. For one

THE AMERICAN LINE STEAMER "ST. PAUL." LENGTH OVER ALL, 554 FEET. BEAM 63 FEET. DEPTH 42 FEET. TWIN SCREWS. I. H. P. 22,000. DISPLACEMENT 16,450 TONS. SIX-CYLINDER QUADRUPLE EXPANSION ENGINES. BEST SPEED AVERAGE FOR 24 HOURS, 21.78 KNOTS.

service, she may be given great speed; for another, great battery power. Whether either is excessive, that service in naval war alone will show. In considering speed, *per se*, as an element of offensive strength, the weight of expert opinion seems largely in its favour, as compared with other qualities of a war vessel. Passing by American experience in the Civil War, which culminated in the building of the phenomenal *Wampanoag* and her consorts, we find that eminent authority, Mr. J. Scott Russell, F. R. S., saying, as long ago as the year 1863:—

"All that has taken place during the American war has tended to confirm the doctrine I have always advocated, that speed is the first and indispensable requisite of a modern warship."

In the same year, Mr. J. D'Aguilar Samuda said, before the British Institution of Naval Architects, that "the greatest possible speed" was one of the qualities "indispensable to an efficient ironclad navy."

Admiral Sir John Hay, R. N., addressing this institution in 1887, said:—

"I cannot too much urge upon this meeting my belief, as a naval officer, that really the first quality, after seaworthiness, is speed."

Some years since, in discussing, before the same institution, the designs of British battleships, Lord Charles Beresford, R. N., said, in part:—

"Handiness comes into this question of a short ship or a long ship; but, in my humble opinion, the best thing that you can have to enable you to win an action is speed. * * * What is the use of a ship being in an excellent position as regards offensive and defensive power, if she is fighting a faster ship? Speed is the weather gauge."

In the same discussion, Admiral Sir Geoffrey Hornby, G. C. B., said:—

"They (the proposed battleships) have great speed, which I consider is the highest quality that any ship can have; and, mind you, I do not want to put my opinion forward. I go upon the opinion of our highest authority, that of Lord Nelson."

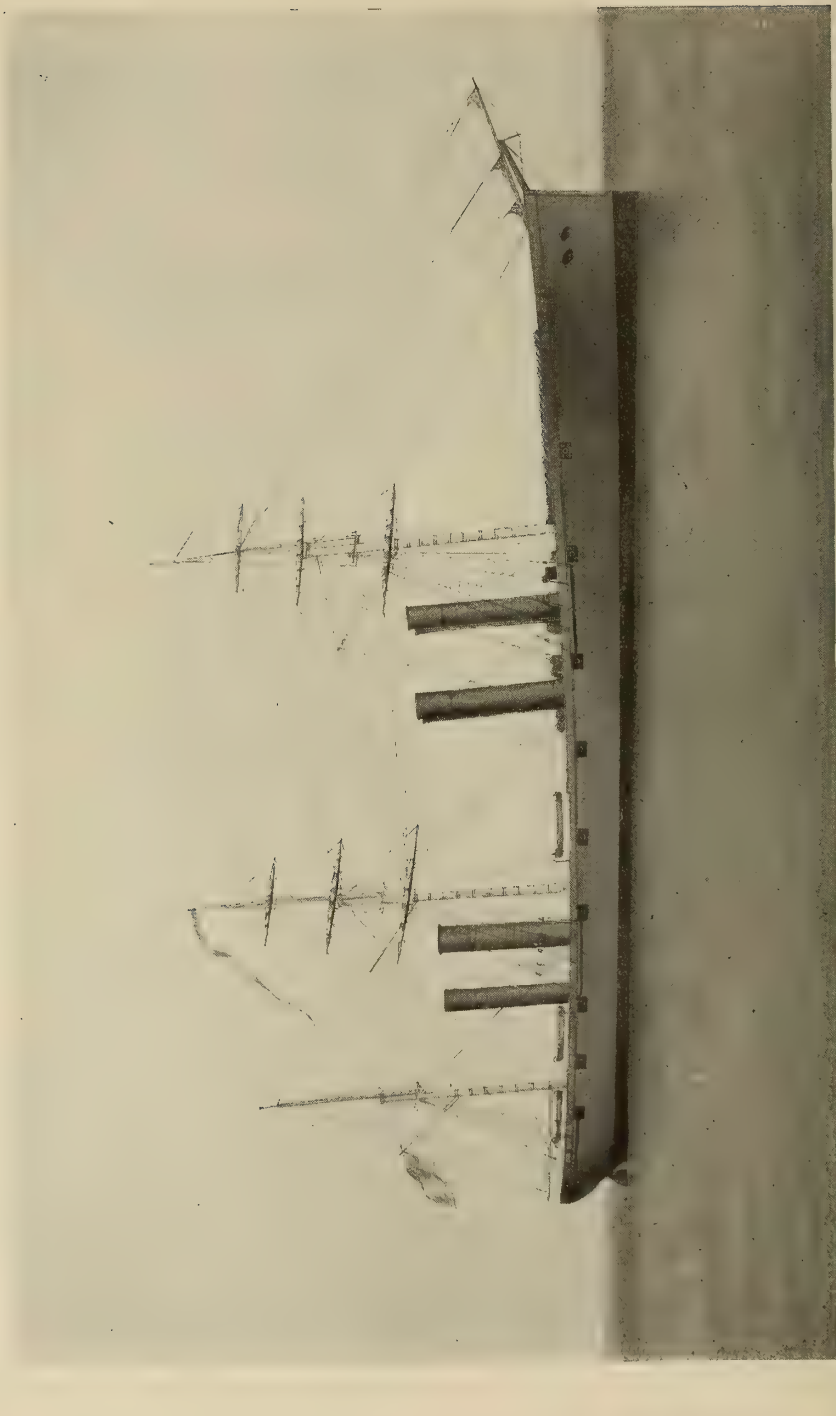
In 1890, Sir Nathaniel Barnaby, K. C. B., in tracing the modern history of armour, showed the everchanging policy as to the extent of its use which the varying needs of the years had imposed upon naval architects. Referring to the fleet of France, he pointed out, that, in 1856, her armoured ships were, above the water line, completely clothed; that from that time onward there was, as to the surface covered, a gradual reduction which reached its minimum in 1886; and that, in 1888, there was a reversal of all this and a return to first principles in the covering again of the entire side with armour. As a rule, the greater the amount of armour, the less the speed, since the former not only implies a heavy battery, but, in itself, adds weight which might otherwise be that of propelling machinery and coal.

In the swift progress of naval science the gun, the means of attack, has distanced, time and again, the armour, the means of defence; and the theory is no longer novel or wholly unsupported that armour will yet be abandoned, that "armoured ships will be as obsolete as mail-clad men." Indeed, Lord Armstrong is credited with the statement that, in the future, "light vessels of great speed, armed with quick firing guns, are likely to be the order of the day." Speed of hull and rapidity of fire would seem to be, with him, the primary essentials.

In 1896, the Right Hon. the Earl of Hopetoun, G. C. M. G., in addressing, as president, the Institution of Naval Architects of Great Britain, said, in part:—

"History teaches us the importance which our forefathers attached to the weather-gauge. It was regarded by them as all-important to that fleet which hoped to assume the offensive. The weather-gauge of to day is the power to outsteam the fleet of the enemy, the power to concentrate quickly, and bring on a general action at the most favourable moment."

M. Georges Clemenceau has given, in the *North American Review* of recent date, vigorous expression to his views with regard to the most effective composition of the French fleet of this day.



THE UNITED STATES CRUISER "WAMPANOAG." BUILT IN 1868 FROM DESIGNS BY NAVAL CONSTRUCTOR B. F. DELANO, U. S. N. ENGINES DESIGNED BY CHIEF ENGINEER B. F. ISHERWOOD, U. S. N. THE FASTEST STEAMER IN THE WORLD AT THAT TIME. TRIAL SPEED, 17¾ KNOTS, OR 22.47 STATUTE MILES.

[Reprinted from "The Steam Navy of the United States," by kind permission of the author, Frank M. Bennett, P. A. E., U. S. N., and the publishers, Messrs. Warren & Co., Pittsburgh.]

After considering the probable foes of France in naval war and the tragic history of the mercantile marine of the United States during the years from 1861 to 1865, his conclusion is virtually that not in slow and massive ironclads, but in a great fleet of swift cruisers there will lie the safety of France and her power of offence.

A notable example of the value of speed is given by Lieutenant T. B. M. Mason, U. S. N., in his report on the action during which the Peruvian ironclad *Huascar* was captured by a powerful Chilean squadron. He says:—

"Grau (the *Huascar's* commander) saw that his only chance of escape lay in his speed. * * * There was but a small difference in the speed of the *Huascar* and her two opponents, but the difference—not so great as half a knot—virtually decided the combat." By less than half a knot, then, the Chileans won.

The recent development in naval science which is perhaps most worthy of note, is the improvement in rapid firing, or rather rapid loading, ordnance, the principle of which has been extended to calibres of six inches and beyond. Too much importance cannot be given to this advance, since, through it, there is obtained an augmentation, otherwise impossible, of the armament and fighting strength. "Consider the position of a ship, which, having fired her large guns, cannot have them reloaded for, perhaps, some minutes. During that interval her adversary could select the most favourable position for attack, and, with quicker loading, although, perhaps, more complicated guns, decide the action." (*Artillery: Its Progress and Present Position.*)

And yet, why strive thus for speed in the loading and the firing of the gun, even at the cost of special mountings, of complicated breech mechanisms, and of fixed ammunition, while still decrying unduly the relative importance of that speed of the ship which serves not only to bring the gun more swiftly to its field of action, but, by quick manœuvering, to vary indefinitely the centre of its arc of train? The speed of hull is, in action, an element of the gun's offensive strength.

But, after all is said, the ultimate test of expert opinion as to the cardinal importance of speed as a factor in sea fighting, lies in the incessant striving to attain it that is seen in battleships to some extent, but most notably in the many cruisers which come in swift succession from the dock yards of the world. It may be possible for the designers of one fleet to err in a "craze for speed;" it is not probable that those of all great navies should go astray in a matter so vital and so costly.

When, in 1894, the *Minneapolis* of the United States Navy, made, with her 20,862 horse-power, a speed of 23.073 knots an hour, on a displacement of but 8005 tons, she distanced, in that speed and for the length of time it was put forth, the records of all previous ships. The *Jus Gentium*, as interpreted in this progressive age, is a cold-blooded code and scant heed is given the quaint dictum of that somewhat antiquated international authority, M. De Vattel, to the effect that "it is impossible that nations should mutually discharge all these several duties, if they do not love each other." Nations, not allied, do not "love each other" so that they see, with unmixed pleasure, foreign war material increase.

Again, if we receive La Rochefoucauld's saying that, in the misfortunes of our friends, there is always something that is pleasing to us, we must admit also the converse of his cynical aphorism, that, in their good fortune, we have seldom a joy unalloyed. And so, the speedy cruiser and her consort met no warm welcome from watchful naval powers.

On the contrary, the powers referred to seemed ready, at the first opportunity, to wrest her laurels from her. By far the larger proportion of the first-class cruisers, armoured or protected, which, in recent years, have been projected or completed, are ships with speeds varying from 19 to 21 knots; and, of those which equal or exceed 22 knots,—projected, building, or afloat—there is now a moderate fleet, among

THE ARGENTINE CRUISER "NUEVE DE JULIO," BUILT BY SIR WM. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE.

the leaders of which are the British *Powerful* and *Terrible*, armoured cruisers, 14,250 tons, 25,000 horse-power, 22 knots; the French *Jeanne d'Arc*, armoured cruiser, 11,000 tons, 28,500 horse-power, 23 knots; a projected armoured cruiser for Italy of 10,500 tons, 13,000 horse power, 23 knots; the *Buenos Aires* of Argentina, protected cruiser, 4500 tons, 14,000 horse-power, 23.2 knots; the Chilian *Blanco Encalada*, protected cruiser, 4420 tons, 14,500 horse power, 22.78 knots; the *Nueve de Julio*, of Argentina, protected cruiser, 14,500 horse-power, 22.74 knots; and the *Yoshino*, of Japan, an improved form of the latter vessel, with a speed of 23.08 knots. It would seem that expert opinion favours extreme speed for large cruisers.

It needs but a glance at the records of the world's shipping to show, therein, Great Britain's paramount position. In this, as has been said most aptly, it is "*Athanasius contra mundum*," with England replacing the disputatious primate. The mercantile marine of the world comprises, according to Lloyd's Register for 1896-7, 29,880 vessels of 100 tons or more, with a tonnage aggregating 25,614,089. Of these, Great Britain owns 11,880 vessels, whose total tonnage is 13,359,026, or more than a third of the fleet in number and more than one-half in tons. As to other countries, they lag so far behind their leader in the race as to recall the once famous phrase, "Your Majesty, there is no second."

The United States, however, surpasses easily any of the remaining countries, with her 3215 vessels of 2,234,725 tons,—a number and tonnage measurably exceeding those of either Norway, Germany, or France, which, in succession, follow her. The meagre size of this fleet, as compared with her vast foreign trade, is shown most forcibly by the percentage of the foreign commerce of the United States carried in American vessels, computed at ten-year periods, as follows:—1861, 66 per cent.; 1871, 36 per cent.; 1881, 26 per cent.; 1892, 12 per cent.

Turning again to Mr. Cramp's keen and powerful analysis of the existing conditions of American shipowning and shipbuilding, we find him estimating the amount yearly lost to America in freight and passenger tolls and in the industrial increment represented by the necessary shipbuilding, as over three hundred millions of dollars. Of this, he says:—

"It is a constant stream of gold, always flowing out. The foreign shipowner who carries our over-sea commerce, makes us pay the freight both ways. For our exports we get the foreign market price, less the freight. For our imports, we pay the foreign market price, plus the freight. No fine-spun theory of any cloistered or collegiate doctrinaire can wipe out these facts."

There would seem to be, in this, some warrant for the bill introduced recently in the Congress of the United States whose intention is to promote the restoration of the American merchant marine by imposing a discriminating duty upon all imports carried in foreign bottoms. In addressing the Senate on this measure recently, Senator Elkins, its able advocate, is quoted as saying, in part:—

"The United States pays $500,000 every day, or nearly $3 per capita per annum, to foreign shipowners for carrying what its people sell and buy,"—an enormous tribute, indeed, to foreign rule of the sea. This act has a somewhat drastic prototype in the law, passed at Cromwell's instance in 1651, which provided, in part, that no goods should be imported into, or exported from, England except in English vessels.

It is to be remembered, however, that the mercantile marine of the United States is small only when compared with that of the greatest trader of all lands and ages. Feeble as it is, thus relatively, it represents actually commercial interests of large proportions and great valuations, with, as well, the potentialities of the unknown future.

Its importance is indicated, to some extent, in the approximate value of seaborne commerce as given by Sir George Clarke, for four nations, during the year 1891, thus:—

THE CHILIAN CRUISER "BLANCO ENCALADA." BUILT BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD.

British Empire	£970,300,000
United States	357,700,000
France	300,200,000
Germany	212,000,000

In his work, "The British Fleet," Commander Robinson, R. N., gives, in brief, a navy's right of being, when he says that "it (the English Navy) has tended to grow with the growth of commerce, and that it has always been based upon commerce and upon the existence of a merchant marine." There can be for commercial nations then, in considering naval war, no subject of more importance than the attitude of the fleet toward the sea-borne commerce of a hostile country.

The great Napoleon and many lesser men have contended ably and speciously for the immunity of the maritime commerce of an enemy; but to this there need be no other answer than that given broadly, but with admirable clearness, by Captain Mahan:—

"For what purpose, primarily, do navies exist? Surely not merely to fight one another—to gain what Jomini calls the 'sterile glory' of fighting battles in order to win them. If navies, as all agree, exist for the protection of commerce, it inevitably follows that, in war, they must aim at depriving their enemy of that great resource. * * * It is a fair deduction from analogy that two contending armies might as well agree to respect each other's communications, as two belligerent States to guarantee immunity to hostile commerce."

In commenting on the careers dur-

THE JAPANESE BATTLE-SHIP "YOSHINO." BUILT BY SIR WM. G. ARMSTRONG, WHITWORTH & CO., LTD.

THE U. S. MAN-OF-WAR "KEARSARGE."

ing the American Civil War of the famous *Alabama* and her consorts, Professor Soley says, as to commerce destroying, that "it fulfils, in an extraordinary degree, the main object of modern war, the crippling of an adversary;" and, again, "other governments, in case of war, will deem themselves fortunate, if they can rival the achievements of the Confederate commerce destroyers." It may be accepted as axiomatic, then, that in successful warfare on the sea, waged by, or against, a nation having maritime commerce, the swift cruiser will be a potent factor.

America should need no lesson as to this. Turning again to the history of her Civil War, we find Mr. Scott Russell saying:—"We have seen a fast, unprotected, screw steamer occupy a numerous fleet of the enemy's vessels in the simple duty of pursuing her. We have seen that, for that purpose, neither heavy armament nor iron coating (armour), nor any other quality (but speed) has been of the slightest value. Owing to her superior speed, she has continued to infest the shores and prey upon the mercantile fleets of the North; she has been pursued, but unharmed, by a whole navy."

And, with what result? In 1872, the tribunal at Geneva made an award of about fifteen and one-half millions of dollars for direct damages done the shipping of the United States by one or more armed vessels. The indirect damages—which that tribunal did not admit—were appalling and their effects linger yet. On every distant sea to-day the American flag, in commerce, is seldom seen or wholly missing.

Mr. H. W. Wilson, in his work "Ironclads in Action," shows forcibly the *Alabama's* deadly work. He says:—

"The case of the United States, as presented to the arbitrators, gives the following facts:—In 1860, 'two-thirds of the commerce of New York were carried on in American bottoms; in 1863, three-fourths were carried on in foreign bottoms.' The transfers from

the American to the British flag were as follows:—

1861,—126 ships	71,673 tons.	
1862,—135 "	74,578 "	
1863,—348 "	252,579 "	
1864,—106 "	92,052 "	

"The *Alabama's* career began in the autumn of 1862. Its effect is manifest."

The Geneva award did not cover fully even the actual losses on ships and cargoes, claims for which were presented to the tribunal. The acts of eleven Confederate cruisers were cited in the American case with a sum total of claims filed up to October 25, 1871, of "$17,900,633.46, all but about four millions of it being charged to the account of the *Alabama* and *Shenandoah*"—the *Alabama's* share being about $60,000 greater than that of the *Shenandoah*, and amounting to $6,547,609.86. "The tribunal decided that England was in no way responsible for the $1,160,153.95 of losses inflicted" by six of these cruisers (*Century Magazine*).

Americans can look backward now, under the happier influence of a later and more kindly time, dispassionately on all this. Its true history has grown clearer with the years, and it is possible now to differentiate between the acts of Lord John Russell and his supporters and those of the great masses of the English people, whose warm sympathy for the American North held him in check. There is unforgotten, too, the action of the Queen and the Prince Consort in the *Trent* affair; and the self-sacrifice of the mill operatives of Lancashire, who, destitute and starving as they were, never gathered to ask the recognition of the Confederacy, which would have brought to them, so quickly, Southern cotton, work, wages, and food. John Bright, in his stirring and noble words, spoke for the great body of his countrymen and voiced the true spirit of his nation in that time.

THE AMERICAN CONFEDERATE CRUISER "ALABAMA," DESTROYED OFF CHERBOURG, FRANCE, ON JUNE 19, 1864, BY THE U. S. CRUISER "KEARSARGE."

And so, let darker memories fade! Let there come, under due safeguard, arbitration—the end of wars, the "Truce of God"—between the branches of the Anglo-Saxon race! The ultimate purpose, the lofty aim, are the

THE CHILIAN TWIN-SCREW CRUISER "ESMERALDA." BUILT BY SIR W. G. ARMSTRONG, WHITWORTH & CO. LTD. DISPLACEMENT, 7000 TONS. I. H. P., 16,000. SPEED, 20 KNOTS.

same with both peoples, whatever their governments of a day may do. Of both, then, may be said, as has been said so well of one,—

"Where the footfall sounds of England, where the smile of England shines,
Rings the tread and laughs the face of freedom."

The naval moral which should, however, be pointed out is that the *Alabama* and her sister ships, which wrought such widespread havoc on the seas, were but cruisers—not even "protected" at that; and that the *Kearsarge* which, at last, sent her beneath the waves was but another—and a little faster—cruiser. In such work, the great battleships will have no part. With their relatively low speed and coal endurance, they will patrol no ocean highways, sink no *Croiseurs Corsaires*, convoy few merchantmen, and overhaul no fast mail steamers. Their station is in the fighting line where Greek meets Greek.

The primary requisites for the destroyer seem to be, after a light battery, speed and sea-keeping power. While armoured tonnage can guard merchantmen from her assault, yet her "field is the world" and no nation could police, with armoured vessels, every sea. That speed should be the highest attainable, consistent with a sufficient battery and coal endurance. What would it avail to build so-called "destroyers" at 18 knots, with a number of swift foreign liners making 21, or more, and capable, each of them, of becoming modern *Alabamas* on distant seas?

It is quite true that the vast bulk of ocean commerce, "the cargo steamers that carry the nation's necessities at less than 14 knots," are open to attack by cruisers of moderate speed; but what of the twenty or thirty "Atlantic greyhounds" and the swift ships of other oceans? Of steamers, whose speed at sea ranges from 19 to 22 knots, there is already a fair fleet. Great Britain has six in the *Lucania*, *Campania*, *Majestic*, *Teutonic*, *Umbria*, and *Etruria*; the United States, four, the *St. Paul*, *St. Louis*, *New York*, and *Paris*; Germany, five, the *Fürst Bismarck*, *Normannia*, *Columbia*, *Spree*, and *Havel*; France, one, the *Tourraine*; and Russia, five, the *Kherson*, *Kief*, *Orel*, *Petersburg*, and *Savotoff*.

Turning again to the criticisms of the American commerce destroyers, it would seem, as to "the merchant ship of the same type" as the *Columbia*, and practically her equivalent, that this is but the echo of an old cry against her type. Over a score of years ago the Right Hon. Earl of Lauderdale, Admiral, R. N., said that, in the event of war, "you have only to hire these vessels (fast merchant steamers) and my belief is that, instead of building an enormous navy of unarmoured vessels to protect our trade, this would be much the quickest and the cheapest way of doing it."

It would appear further that the equivalents in the mercantile marine of such swift cruisers do not exist. The liner approaching her in speed is much longer and lacks, therefore, her manœuvering power. She is, in structure, radically different and could be sunk by one well-planted shot, while the water-tight subdivision and cellulose belt of the cruiser will protect her from serious injury by light gun fire.

Again, the harbours of the United States are, many of them, too shallow to admit the great liners. The large Cunarders draw about 30 feet, while the maximum draught of the *Columbia* on her transatlantic run was 26 feet 3 inches,—a difference which widely extends the number of ports open to her. Her draught, also, can be materially reduced should occasion require it, having been but 23 feet 8 inches on her contract trial.

It is, however, when the vital problem of protection to propelling machinery is approached that the weakness of the merchant steamer seems most apparent. This question has been ably discussed in an exhaustive work entitled "The Steam Navy of the United States," by F. M. Bennett, United States Navy.

Mr. Bennett shows first that the engines and boilers of the *Columbia* are not only below the water line, but are, in addition, shielded by a protective deck. After discussing the arrangement on the Atlantic liner *Paris*, as typical of that common to many mail

FROM A PHOTOGRAPH BY WILLIAM H. RAU, PHILADELPHIA.

THE BRITISH CRUISER "BLAKE," TWIN SCREWS. INDICATED H. P., 14,450. DISPLACEMENT, 9000 TONS. SPEED, 19 KNOTS.

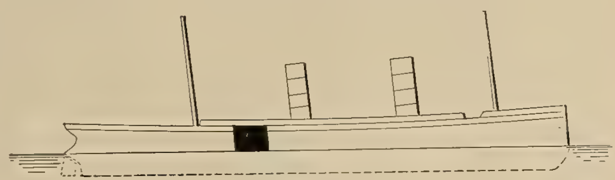
steamers and in which the cylinders and other vital parts are above the water line, he proceeds, as follows:—

"A different and more recent arrangement is that of the latest steamers of the North German Lloyd, adopted also in the *Campania* and *Lucania* of the Cunard line, which economises fore-and-aft space by placing the high-pressure cylinders over the low-pressure. The large Cunarders named have five cylinders to each engine, the intermediate pressure in the centre, and a tandem pair of high and low-pressure cylinders at each end.

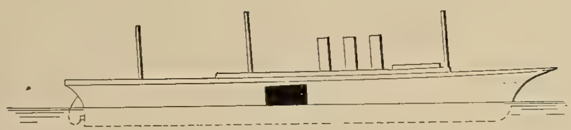
"The height of these engines from bed plate to top of high-pressure cylinders is 47 feet, and the foundation framing under them is 8 feet in depth. Therefore, they stand, when the ship is drawing 30 feet of water, at a height of 25 feet above the water line, making, with their fore and aft extent, a target 25 34 feet, in any part of which a shot or shell would most surely disable one engine and probably both; this, furthermore, without reckoning the danger to steam, exhaust, and receiver pipes leading to and from the cylinders. The same target, in the case of the *Paris*, would be 38×16 feet, both graphically illustrated in the diagrams on this page. The boilers of these steamers are below the water line, but without any protection for themselves or their pipe connections against glancing shot or bursting shells."

It is evident that only a blind gunner could well miss such targets; it is evident, further, that the problem of furnishing armoured protection for such a space, with the piping not therein included, would prove, in the typical "greyhound," a problem difficult, if not impossible, of solution. Armed merchant ships have their field in warfare, but they cannot replace fully the fast cruisers. Assuming, however, that such merchant ships are the full equivalents of the *Columbia* and her class, the question may well arise as to where, in the hour of danger and with her relatively feeble marine, the United States shall find them.

On March 3, 1891, an act was passed by the American Congress, relating to the ocean mail service, to the promotion of commerce, and, incidentally, to provision for auxiliary naval cruisers. Under this act, all vessels employed in the mail service are inspected by officials of the Navy Department and classified as to speed and other qualities. In the



CAMPANIA.



PARIS.

report of the Chief of Ordnance of October 1, 1896, the results, to that date, are given as follows:—

Of the first class, *i. e.*, steamers of 20 knots' sea speed and not less than 8000 tons, there are four. Of the second class, *i. e.*, steamers of 16 knots, minimum tonnage, 5000, there are none. Of the third class, *i. e.*, steamers of 14 knots, minimum tonnage, 2500, there are thirteen on the Atlantic and four on the Pacific coast. Of the fourth class, *i. e.*, steamers of 12 knots, minimum tonnage, 1500, there are two on the Atlantic and five on the Pacific coast.

Excluding the four vessels of the first class,—the magnificent steamers of the American Line,—the list includes no potential cruisers of much value, but seems, at best, but a feeble aggregation of small steamers of very moderate speed.

In summing up what has been set forth herein, with regard to the commerce destroyers and other swift cruis-

ers of the United States fleet, it is noted that the nation—which, in naval affairs, has slept, for a score of years, a Rip Van Winkle sleep—seems now awaking to its possibilities upon the seas. While its naval rehabilitation has been somewhat slow, if measured by its modern ships afloat, and while its naval policy has been sometimes fitful and spasmodic, there seems no doubt that, with its vast resources, the widespread loyalty to the flag, and the traditions of a gallant navy to give inspiration, there will be demand not only for a large fleet, but for one so varied in its composition as to be effective in every service.

It has been seen that, in the speed of the American commerce destroyers—whose relative importance has been decried unduly—those ships have been given a quality of offensive attack—upon commerce, in particular—which expert opinion esteems as of great importance. There has been shown further the vital part which the defenders or assailants of sea-borne commerce must perform in naval war. And, finally, there seems apparent the absurdity of the claim that the places of the swift, protected cruisers can be filled, in time of need, by merchant steamers; and that, even if this were so, the United States has, practically, no fit mercantile marine toward which to turn for such replacement.

The question as to the cruiser element of modern fleets is a vexed one—notably so in France, as to whose present naval strength some of her experts voice a fear. "*Nous n'avons pas la flotte de notre politique*," says M. Kerjegu in pessimistic words. Her authorities seem unsettled and her officers divided as to the constitution of that fleet—one faction contending for massive battleships to meet the Triple Alliance, the other eager chiefly for swift cruisers and torpedo boats to prey upon the commerce of England, her historic foe.

For many services of naval war, the cruiser of high speed has no peer; but, despite the testimony of the Yalu, her offensive value in line of battle is still unsettled. It is to be remembered, however, as to this, that the battleship, like the cruiser, is a combination of compromises; that she is not equally strong throughout and in all positions. On this point, Lieutenant Niblack, U. S. N., a tactical authority, says:—

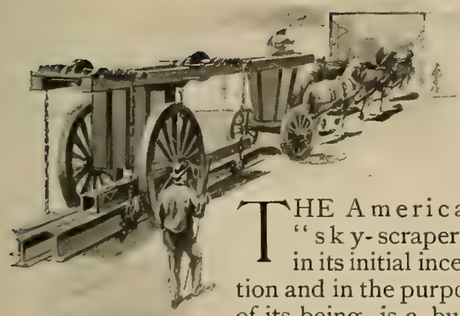
"A modern battleship is now defensively stronger in her bow presentation than in any other; for her armour offers there its least area, best deflective angle, and its greatest concentration."

Then, too, the battleship's speed is but moderate, her main battery is not of the rapid fire system, and her lighter guns lack, sometimes, strong protection. Points such as these may, in combat, give the cruiser an offensive value that is not considered now; and there seems force in the contention of Captain May, R. N., that it may be possible for two or more swift cruisers to attack successfully—by torpedoes at least—a powerful battleship.

THE TALL BUSINESS BUILDING.

Some of its Engineering Problems.

By Dankmar Adler.



THE American "sky-scraper," in its initial inception and in the purport of its being, is a business proposition. It is erected for the advancement of the business interests and the enlargement of the income of the owner of its site. It cannot be considered as being monumental of anything but human greed and of man's desire for gain, and of the professional ingenuity and skill which have been created and developed by the wants of our civilisation.

Capitalists, speculators or promoters decree that a given site be so enclosed that its area shall be multiplied by twelve, fifteen, twenty, thirty or more, that the resultant enclosed space shall be devoted to certain business uses, and that the structure thus created must yield a net revenue equal to a certain percentage upon the capital invested. The financial problem thus presented would not have been conceived had it not been for two achievements of American engineering skill,—the invention of the high speed hydraulic elevator, and the development of the skeleton, or steel cage, system of construction; nor can it be successfully solved without the aid of engineering skill of the highest order, covering almost the entire range of architectural and engineering science and practice.

If the proposed structure is to yield the desired financial return, its general plan of management must be adapted to the requirements of its intended occupants. The means of communication from the street to every part of the building must be ample, safe, direct and time-saving. Generous provision must be made for admitting light and air to every part of enclosed space. Stability, permanence and safety of structure, and sufficiency, efficiency and safety of mechanical equipment must be provided for in such manner as to prevent even the slightest suspicion of the lack of either of these essential characteristics and qualities of high-grade engineering work. Water supply and drainage, temperature regulation, artificial light, telephone and telegraph connections, arrangement for the storage of valuables, facilities for receiving and distributing supplies for the service of the building and the goods and chattels of its occupants, the maintenance of cleanliness and the disposal of waste and rubbish, apparatus for preventing the spread of fire in the contents of the building and appliances forprotecting the steel structural members from injury by fire; these and many other details are essential factors in the successful design of the modern building of the skyscraper type.

And while considering and determining all these, the commercial character of the undertaking must be kept in sight; and with this consideration comes the consciousness that tenants, clients and customers must be coaxed to come into the building, which, in order to attract them, must possess a distinctive charm of external presentation, and a liberality and sumptuousness of internal appointments which arrest the attention

THE AUDITORIUM BUILDING, CHICAGO.

Messrs. Adler & Sullivan, Architects, Chicago

of even the superficial observer and appeal to his emotion and sentiment before his intellect takes in and appreciates the fulfillment of material wants afforded by plan, construction and equipment. And ever dominating all other considerations there remains the necessity of maintaining the proper commercial ratio between cost of structure, cost of operation and possible income.

Although the desire to draw a great income from capital invested in occupation of a very high stratum of air above a given building site may take lodgment in the imagination of any man or group of men, it is impossible of realisation except through the agency of the master mind of an architect or a chief engineer, which, conscious of all the requirements of the situation, conversant with the arts and sciences by whose aid these may be fulfilled, in touch and in sympathy with the mental equipment of the best specialists in the various departments of artistic, scientific and executive activity upon whose aid the success of the enterprise depends, can marshal, arrange, co-ordinate and direct the forces which are to bring about the desired end. Such master mind only can conceive a general plan, the development and execution of which will give its proper place and due importance to each major and minor requirement of the situation.

A plan so conceived will be found fulfilling the requirements as to form, dimensions, light, air and accessibility of rooms and corridors; and the partitions

which circumscribe these will be so designed as to coincide with lines of support and windbracing, with the position and direction of steam, water and waste pipes and of wire conduits, while the positions and dimensions of windows will be at once adapted to the intended occupation and utilisation of the rooms and to the artistic exigencies of the external treatment of the building. Elevators and stairs will be so located that communication between them and the rooms is direct and without tortuous windings, and that the street entrance or entrances are so situated as to serve as main features in the external design and yet allow directness and straightforwardness of approach to the elevators and stairs, and these means of internal communication will be capable of artistic and perhaps monumental treatment.

In a building so designed in its entirety, many of the engineering problems are shorn of dreaded difficulties and their solution becomes simply the working out of the inevitable and logical trend of the underlying idea of the general plan. Posts, girders, windbraces, pipes and conduits of every kind seem to find their places already prepared for them, and rooms, corridors, walls and partitions, doors and windows appear to determine and locate themselves in accordance with the fulfillment of utilitarian, as well as artistic, requirements.

All this seems absurd and beyond the reach of actual attainment in view of all that has been said about the incompatibility of art and the ordinary business conditions which underlie the conception of every project for the erection of a "skyscraper," the irrepressible conflict which rages between the aspiration of art, the tyrannic ukase of sordid, avaricious commercial philistinism, the relentlessly accurate dogmatism of the structural engineer and the scientific enthusiasm of mechanical, electrical, sanitary and other engineering specialists.

But these conflicts and incompatibilities disappear when all participants in the design of the edifice will remember that it is not being created for them or for their arts or sciences, but that all,—artist and artisan, engineer and mechanic, and their art, craft and science,—are but instruments for the attainment of one end,—that of securing, in as short a time as possible, and with as small an outlay as possible, the greatest income which a given piece of realty can be made to yield, that each must subordinate himself and his art and his science to the attainment of that end, and that the purpose of the enterprise cannot be subverted for the glory of art, science or individuals.

A GLIMPSE OF BROADWAY, NEW YORK CITY, WITH THE BUILDINGS OF THE AMERICAN SURETY CO. AND THE MANHATTAN LIFE INSURANCE CO. ON THE RIGHT.

THE ST. PAUL BUILDING, NEW YORK, TWENTY-FIVE STORIES. TOTAL HEIGHT ABOVE PAVEMENT, 317 FEET.

George B. Post, Architect, New York.

The motto of a certain leading American architect is:—"My client, right or wrong." Adopting this motto and with it a firm belief in the correctness of the prognostications and calculations of that client as to the adaptation of the site to certain business conditions and requirements, and as to the tribute which these can pay for shelter in the proposed structure, the problem to be solved by the architect or chief engineer and his staff of specialists will be the creation of the structure best adapted to the fulfillment of the client's declared intentions, and to such possible developments and modifications of these as ordinary foresight and prudence and intelligent anticipation of probable future conditions may present. But this problem is most complex and every effort to solve it develops innumerable minor problems in various departments of architectural and engineering science and practice, the solution of each of which depends upon and influences all of the other subsidiary problems, as well as the great predominant problem of how to bring about the financial success of the proposed undertaking.

The disposition and subdivision of the enclosed space is the foremost problem, and the first element in its solution is the use and occupation proposed for the building by its owners. This may require few rooms or many, large rooms or small, or a combination of both. Under all conditions which may govern the subdivision of space it is possible, no matter how small or how irregular the necessary dimensions of the proposed rooms may have to be, to so adjust and group their spacings, that there will be a regularity and symmetry which permits the introduction of a unit of subdivision. In determining this unit of subdivision the directing factors will be:—(*a*) the necessary dimensions of the rooms resulting from the proposed occupation; (*b*) the requirements of the framing of the skeleton of the building; and (*c*) the exigencies of the artistic expression of the proposed external presentation. Of some influence, but of minor importance, will be the system of heating pipes, plumbing pipes and wire conduits.

The unit of subdivision will also be the unit of construction and the unit of design. If the individual rooms are quite small, it may be well to combine two or even three into one unit. Within certain limits the economy of metal in the construction of the skeleton leads to the adoption of a large unit. The greater relative strength of the deeper beams, the smaller number of connections, the smaller number of pieces to be handled, all favour the large unit; and the reduction in number of pillars, affording greater freedom in subdivision and utilisation of space, will enhance the commercial availability and value of the building.

Again, the greater depth of beams and increased dimensions of pillars enlarge contact areas and riveting surfaces at junction points and thus give better opportunity for attaining a rigidity of connections which is, in itself, a long step toward efficient windbracing. On the other hand, greater beam depths increase the height of each story, which, where there are legal limitations of height of buildings, may cause the loss of a story and, therefore, of its possible rental. Increased span and consequent greater height of beams may involve additional cost of floor arches, perhaps counterbalancing or even exceeding the saving in cost of beams and pillars.

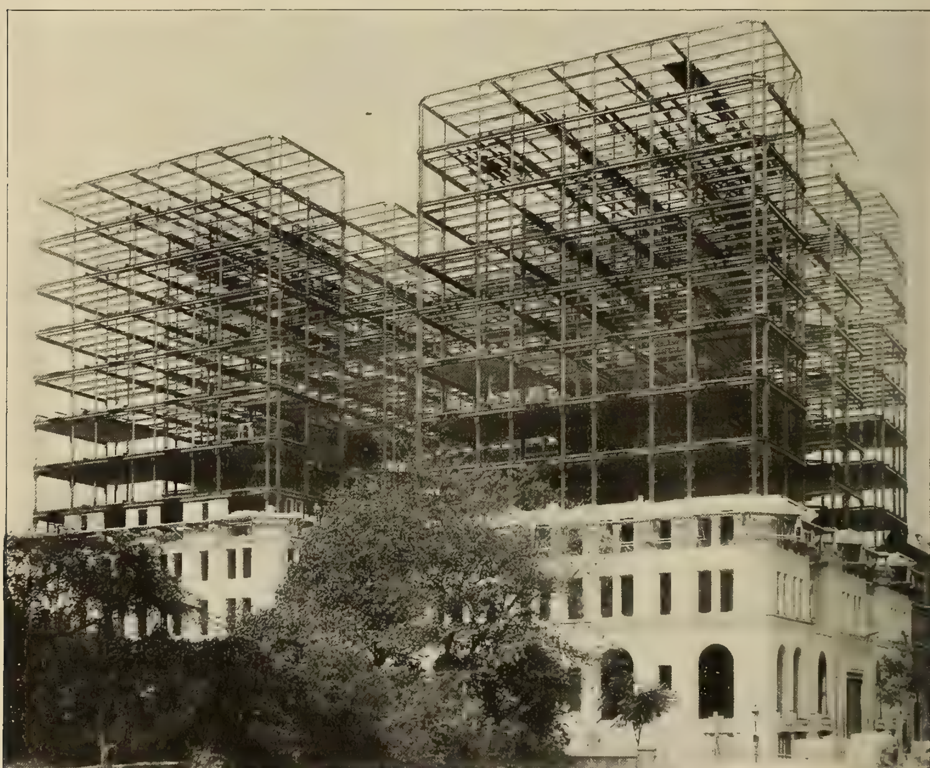
Whether the unit of subdivision be larger or smaller is undoubtedly an important factor in the artistic success of the external treatment of the building, but the personal equation of the designer and so many other varying conditions influence and affect artistic results, that each case must be decided on its own merits. However, the gain in wall surface incident to the use of larger and therefore deeper beams is unquestionably also an aid to the artistic development of the design.

Other elements which affect the decision as to the length of the unit of subdivision are position and dimensions of external and internal light courts (which cannot easily be made too large), elevator shafts, stair wells, smoke stacks and ventilating shafts. All these should be so situated that their lines

coincide with the lines of beam spacing in order that their enclosing walls may become more effective as windbraces. If the building is not rectangular in plan, an effort should be made to confine the irregularities of framing to the outside panels only, and to have at least one wall parallel with the beam lines.

The selection of a unit may absorb much time and thought, but the labour will be profitably expended. True, there may be less freedom and picturesqueness in the treatment of the exterior, but there will be a gain in repose and dignity. There may be variations from ideal dimensions of rooms, but they cannot be very great, and except where preparation must be made for placing special machines and fixtures whose specific requirements will then determine the unit of subdivision, the wants of probable occupants are not so rigid but that they can adapt themselves to the limitations due to room dimensions caused by a well-selected unit.

But note the advantages! With uniform beam lengths there will be uniformity of column loads and, consequently, of column sections, followed again by uniformity of connections at all panel points, and, hence, that frequent repetition of individual parts and details so favourable to rapid and economical work in the processes of mill, shop and erection. Again, where but few types of structural members and connections are required, greater attention can be paid to the refinement and perfection of their design in every detail. The same advantages accrue in connection with internal fittings, such as doors, windows, plumbing and steam fixtures and pipes, wardrobe closets, vaults, etc., etc. If terra cotta is used for an external facing material, the repetitions of detail will reduce cost and expedite prog-



BY COURTESY OF MESSRS. MILLIKEN BROS., NEW YORK.

THE HOTEL MAJESTIC NEW YORK. A TYPICAL EXAMPLE OF STEEL FRAME CONSTRUCTION.

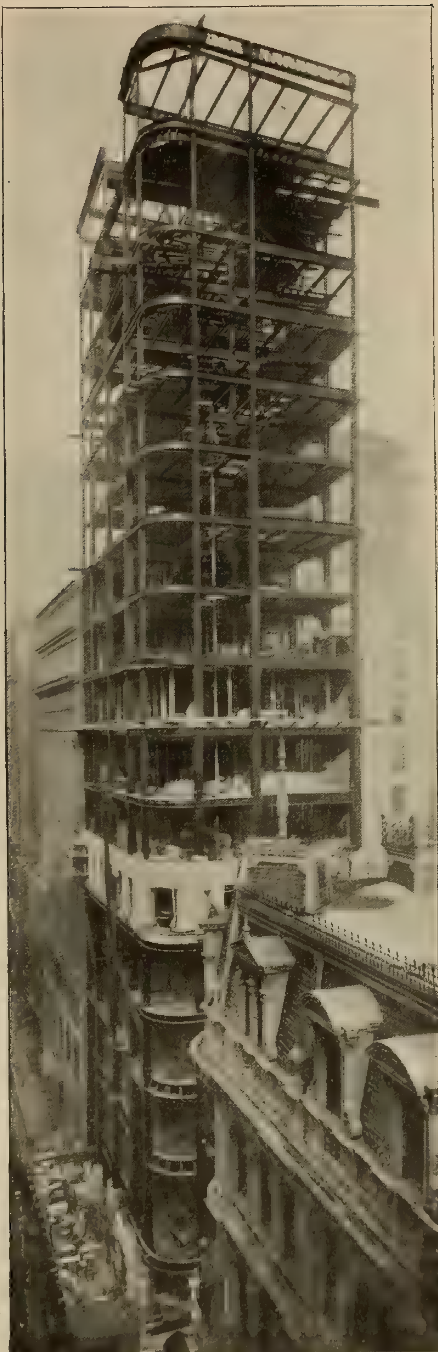
ress. This is an advantage also secured, though in a less degree, if the material for external facing is stone.

Pillars, windbraces, portals, deep girders and other bulky internal structural members, occurring on the lines of a well-selected unit of subdivision may be used as adjuncts of a well-considered scheme of internal decorative effects instead of interfering with all regular arrangement of symmetric treatment of internal wall surfaces and openings as is generally the case where arrangement of rooms and corridors, and the disposition of structural members, are designed independently, each on its own merits as they appear to each individual specialist designer.

The saving of time in preparation of working drawings and erection, due to the use of a well-selected unit, is a most important item. The "sky-scraper" is at best a most expensive structure, erected on ground representing still greater money value. Interest and general carrying charges pile up quite rapidly, frequently exceeding $10,000 (£2000) per month, so that the saving of three months in the time of erection may represent a saving of $30,000 (£6000) or more, in cost of structure; and in cases where competition for tenants is keen, it may mean the taking in of many who would otherwise be absorbed by rival structures.

In short, the unit of subdivision, if its selection is the result of sufficiently careful, thorough and intelligent study of the existing commercial, structural, artistic, and other requirements and conditions, will be found of unending utility from the beginning of working out the drawings to the end of the process of construction. It will as surely and safely lead and guide the architect and engineer in determining the main features of general artistic and structural design as the bone of an extinct animal inspires the naturalist with knowledge of the muscles, viscera and skin of its former owner.

Thus far, all that has been stated relates to the adaptation of the building to existing conditions and wants. So much capital is invested in a modern



BY COURTESY OF MESSRS. MILLIKEN BROS., NEW YORK.

THE QUEEN INSURANCE BUILDING, SEVENTEEN STORIES. HEIGHT, 226 FEET.

Messrs. Geo. Edw. Harding & Gooch, Architects.

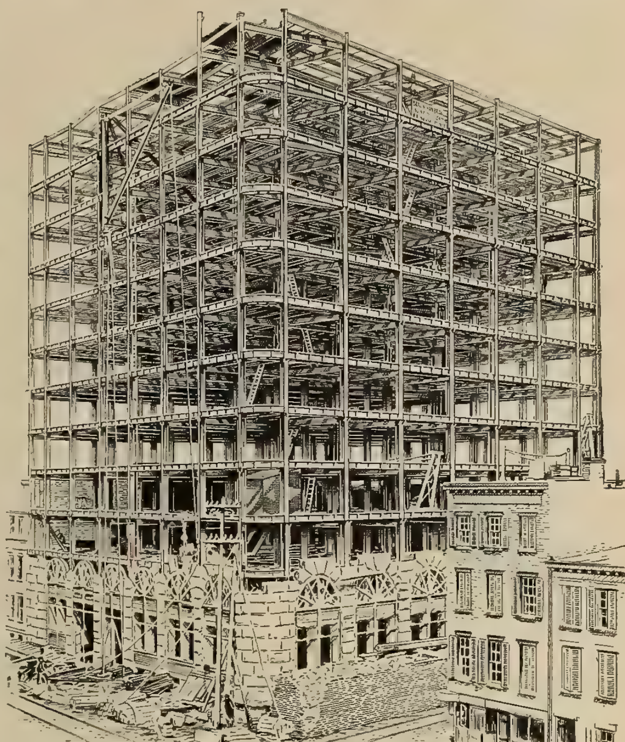
THE TRIBUNE BUILDING — THE AMERICAN TRACT SOCIETY BUILDING, R. H. ROBERTSON, ARCHITECT, NEW YORK. 23 STORIES. TOTAL HEIGHT, 290 FEET. — THE TIMES BUILDING.

THREE CHARACTERISTIC NEW YORK CITY STREET CORNERS.

high building that its design should embody certain general preparations for possible future changes of use and occupation, so far as these can be made without impairing present usefulness; and, above all things, its design should embody all that is necessary for assuring permanence and comparative indestructibility of structure. This at once draws the attention of the engineer to the character of the foundations unless these should fortunately happen to rest upon a uniformly and permanently incompressible soil.

With all its ingenuity and the economy of time and money incident to its application, it must be admitted that the so-called Chicago raft foundation cannot be recommended for use upon compressible soil, by reason of its liability to serious disturbance by future underground works in adjacent or neighbouring streets, but that the footings should be carried through the compressible strata to the underlying rock, and for this timber piling cannot be trusted as affording a guarantee of safety for many scores of years, unless there is absolute certainty of maintenance of water level in the underlying soil. This will, in many cases, make concrete piles, or caissons containing masonry or concrete piers, the only scheme of foundation construction which warrants the permanence of the supports of the structure.

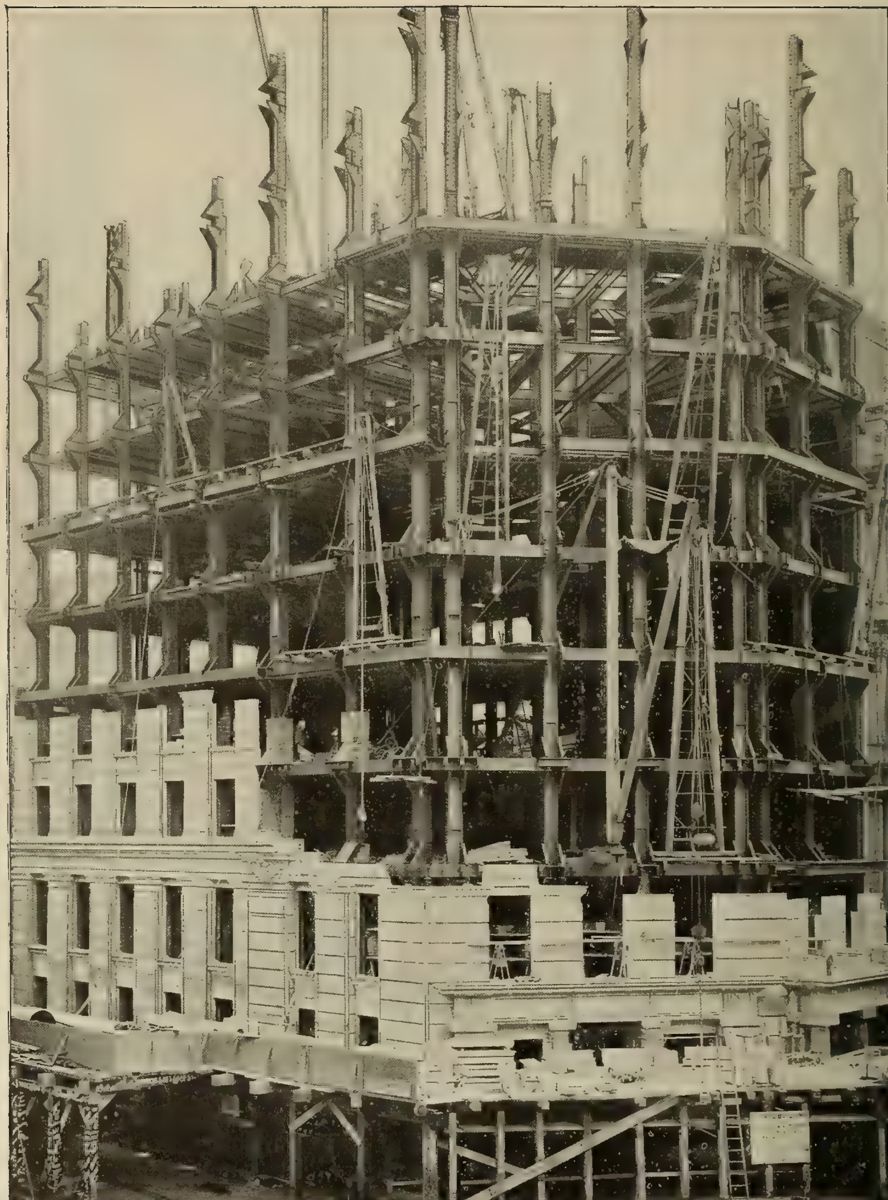
Where a great sum of money is to be invested in a building, the designer should look to permanence of the possibility of continued successful commercial occupation, as well as to permanence of structure. It should be borne in mind that the local contemporary conditions which determine occupation may change in the course of years. If present conditions do not call for great strength of floors and their supports, it is well to remember that a comparatively small percentage, added to aggregate cost of building, can be so applied as to add quite largely to the strength of the main supporting structural members in order that in twenty, fifty or one hundred years, under other conditions, the building can be utilised for purposes not now thought of.



BY COURTESY OF THE BERLIN IRON BRIDGE CO., EAST BERLIN, CONN.

A TWELVE-STORY NEW YORK WAREHOUSE.

A carefully worked-out system of skeleton construction is particularly well adapted to possibilities of adaptation to changing requirements, and it may here be said that this possibility of change of occupation rather favours the adoption of a large unit of subdivision; for freedom from posts and other obstructions will never be in itself detrimental, no matter for what a building is to be used, while if future developments and



BY COURTESY OF MESSRS. J. B. & J. M. CORNELL, N. Y.

THE ST. PAUL BUILDING, NEW YORK, DURING ERECTION.

George B. Post, Architect, New York

changes demand capacity for very heavy loading, this can be attained, when the necessity arises, by inserting additional pillars into the wide spacings first provided, assuming that when loading is exceptionally heavy, close spacing of posts is not usually objectionable.

In connection with a reasonable regard for possible future changes in the internal subdivision and use of any building, there will be a natural preference for those safeguards against wind pressure which can be applied with a minimum of disturbance to occupation of floor space.

With all our pride in the achievements of modern architecture and engineering as exemplified in the construction of the modern high business building, we must not forget that structures equally tall, or even taller, have been reared in former generations, and demonstrate by their continued existence that there were, long before our day, architects and engineers whose command over the materials and forces which make for stability and permanence of structure was at least equal to our own. Yet these ancient structures are altogether unutilitarian and could not have been otherwise by reason of the absence in the day of their erection of means of lifting great loads to great heights in quick time and at small cost.

The quality of utility which characterises the tall structures of our day is due to the invention of the elevator; and the elevator, not the skeleton construction, has called the modern high business buildings into being and remains their distinguishing characteristic. It is, therefore, essential that the location, arrangement, construction and operation of the elevators be given foremost consideration in designing the equipment of any high building.

Fortunately, the progressive and intelligent spirit of the leading American elevator builders has solved the problems relating to safety, smoothness of operation, and promptness and certainty of control of elevators running to all required heights, at all necessary speeds.

The problem before the architect and the engineer is adaptation of one of the many known and tried types of elevator machine to the peculiar conditions of the particular building in hand, as also determination of location and number of machines, and size and form of cars. The cars should be wide and not deep, and they should have large doors. In connection with this it should be remembered that the arrangement of elevators on arcs of circles in plan tends to contraction of their door openings and to corresponding diminution of their usefulness.

While up to a certain point concentration of elevator service is an advantage, experience has shown that there may be so many elevators in one place as to cause congestion of traffic and an annoying confusion to those watching for elevators in which to embark for upward or downward trips. This leads to the belief that in very large buildings it may be well to divide the elevators into two or more groups, even if this should involve greater outlay for first construction, as also for operation and maintenance.

Excepting that the possibility of short circuits and grounds as well as the dangers arising from accidental overheating and from leakages of water threaten the reliability and safety of even the best of electric elevators, there is little choice upon the score of safety, smoothness of operation, and certainty and promptness of control, between hydraulic and electric elevators. It may be that by elaborate precautionary measures the specific danger peculiar to the use of electric current as a motive power can be eliminated. If this is done, there remains merely the question of structural and commercial adaptability of either type to the peculiarities of each successive building.

In very large buildings in which there are many elevators running to great height, and in which there is a local steam plant in daily operation, the writer would award preference to the high-pressure, plunger type of hydraulic elevator, while for smaller buildings in which the shutting-down of steam plant during the summer is considered desirable, preference may be given to the

BY COURTESY OF MESSRS. MILLIKEN BROS., NEW YORK.

THE COMMERCIAL CABLE BUILDING, NEW YORK, TWENTY-TWO STORIES. HEIGHT TO TOP OF DOME, 304 FEET.

Messrs. Geo. Edw. Harding & Gooch, Architects, New York.

THE GUARANTY BUILDING, BUFFALO, NEW YORK.

Messrs. Adler & Sullivan, Architects Chicago.

THE BOWLING GREEN BUILDING, NEW YORK, SIXTEEN STORIES. HEIGHT, 234 FEET.

W. G. Oudsley, Architect, New York.

electric elevator, and, among electric elevators, to that whose application of power from motor to car is most simple and direct, always assuming equal efficiency of controlling mechanism and safety devices.

In very high buildings division into "way" and "express" elevator systems is almost essential. In such cases very high speeds,—even 800 to 1000 feet per minute may be given to the latter, while cars stopping at every floor should not travel at higher speed than 400 feet per minute. Indicating and signalling devices may be of great service, and upon their efficiency may depend the possibility of making a smaller number of elevators do the work for which a larger number would otherwise be required.

The number of elevators required for a given number of offices depends upon the height of the building and upon the business of its tenants. A building containing many small offices, each having a separate tenant, requires more elevator service than one given over to the use of large corporations, a great portion of whose business is transacted by correspondence and among its office employees. Eight to ten elevators will be ample for a building containing 480 offices, divided among twelve stories; but if the same number of offices were distributed among twenty-four stories, then, other things being equal, a larger number of elevators would be necessary.

The preparations to be made for hoisting freight may, if the exigencies of the general disposition of space permit, be in the shape of a special and separately located heavy, slow-moving machine to be used for the carrying of freight only. But it will often be necessary to adapt one of the passenger elevators for carrying furniture, books or safes. Arrangements for carrying variable loads are probably more readily made in hydraulic than in electric elevator mechanisms.

Heating apparatus must be so designed that steam will circulate freely through all its pipes and radiators under a pressure of not more than about one pound above the atmosphere. An efficient system of automatic temperature control is always desirable, but not necessarily attainable. All risers should be insulated and carried in closed ducts. However desirable a system of indirect radiation with forced draught may be, there is never room in a high structure for all the necessary air ducts, though there may be enough for the service of a few of the lower stories. In any event, space will be required for the air ducts incidental to the ventilation of boiler and engine room, toilet rooms and for kitchens and bath rooms, if such are in the building.

The question always arises whether it is best to operate the steam plant through the whole year and to generate within the building not only steam for heating, but also for operating elevators, pumps, fans and lighting apparatus; or, whether it is preferable to shut down the steam plant in summer and purchase electric current for driving elevators, pumps and fans, and for lighting. In a large building the former, and in a small structure the latter is more economical. The latter course leaves the building cooler in summer, but in the spring and autumn the necessity for occasionally warming the building for but an hour or two at a time, gives rise to annoying conditions. In estimating cost of operation under both systems, the heating value of exhaust steam and the salaries incidental to the running of the heating apparatus must be considered, as also the fact that there must be, in either case, a competent chief engineer employed during the entire year to look after the machinery of the building.

But no matter whether light and power are generated in the building or taken from an outside source, it must be remembered that a large modern business building consumes a greater volume of steam and its products,—heat, power and light,—than any but the largest manufacturing establishments, and that the allowance of space for the machinery department should be made extremely liberal, so as not to cripple the service and thus increase operating expenses. The boiler and machinery rooms should not only be of ample area, but also quite high; twelve, fif-

THE POSTAL TELEGRAPH BUILDING, NEW YORK, FOURTEEN STORIES. HEIGHT, 192 FEET.
Messrs. Geo. Edw. Harding & Gooch, Architects New York.

teen or twenty feet will not be excessive, becuase this will permit the use of better types of boilers and furnaces, greater range of choice of engines, better facilities for running pipes, etc. The use of Shone ejectors makes it possible to fix the floor level of engine and boiler rooms below sewer level.

The boilers should be adapted to carry high pressures, even if it is determined not to install a power plant in the building. This will not impair their efficiency for heating purposes, but they will be ready for use under higher pressures if, for any reason, it is afterward determined to generate light or power in the building. It is worth great effort to locate boiler and machinery rooms and construct their enclosing walls and ceiling in such manner as to prevent transmission of heat to other parts of the building. Inattention to this detail may affect rental values of important rooms.

In selecting engines for driving dynamos and for pumping it is not necessary to expend very large sums for the purpose of attaining minimum steam consumption. Some of the exhaust steam can be used throughout the year for heating water; everywhere in the United States, north of the Ohio River, all the exhaust steam can be utilised during six or seven months of each year; and for from three to four months the exhaust steam will not be sufficient to supply the demands of the heating apparatus. Therefore, simplicity of construction, smoothness, regularity and noiselessness of operation, accessibility of all parts for purpose of repairs, compactness and such degree of economy of steam consumption as can be attained without excessive increase of cost of installation and attention should be the controlling factors in selecting the engines.

On the other hand, feed water heaters and purifiers, appliances for maximum utilisation of exhaust steam with minimum back pressure, water heating and circulating apparatus for the plumbing fixtures, appliances for minimising the annoyance to tenants from the noise and dust arising from the handling of fuel and ashes, apparatus, tools and appliances necessary for quick repairs, and everything else which will help in the better maintenance of the plant and the comfort of the occupants of the building, should be the best that money can buy.

Under the most favourable conditions of external exposure, there will be places in every large building which cannot be ventilated except by mechanical means. For those which are apt to be malodorous or excessively warm a vacuum system should be used, discharging if possible above the roof. For inhabited rooms a plenum system or a combination of plenum and vacuum is generally to be preferred. In all cases fans and their propelling motors must be large for their work, and placed so as to be easy of access. Nor should there be any false economy of space in designing air ducts; this also applies to the smoke stack and to ducts for pipes, elevator cables and counterweights, and for electric cables. These ducts should be so located and proportioned as to permit free access to every pipe, cable, sheave, counter weight, or other fixture. Horizontal pipes also should be run in ducts and made accessible throughout their length.

In determining the number and capacity of dynamos, it is necessary to note the difference between minimum average and minimum loads and the time range of each. It need hardly be stated that dynamos, direct-coupled to the crank shafts of the engines, should be selected for this service, that ample space be provided for access to all parts of these machines, and that their location and that of the switchboard be where it is cool and where there is light.

In running feeders from the switchboard to the centre or centres of distribution, allowance should be made for maximum consumption of current.

But without having accomplished more than a mere skimming over the surface of things, this article already occupies all of the space assigned to it, without giving attention to many important engineering problems which are encountered in the design and erec-

tion of every modern high business building. The reader who wishes to pursue the subject is referred to the writings of Mr. Gerhard, Mr. Kidder and many other eminent specialist who have enriched the literature of the building arts and sciences.

The writer will have accomplished his object if he has succeeded in demonstrating that to attain the highest possible degree of commercial success in the erection of a tall business building, it is necessary to rear a structure which is at once a work of art and a realisation of the best in the science and practice of structural, mechanical, electric and sanitary engineering; that this many-sided perfection can be reached only by the co-operative action of the many minds whose work is made tributary to the purposes of the enterprise, and unless there is, from the very first, a comprehensive grasp of all the requirements of the situation and of all the contributing forces and elements, and a consequent adaptation and co-ordination of all to one central purpose, the result will be chaos, and partial, if not total, failure.

It is an elevating and ennobling sensation to be conscious of the act of drawing out, developing and directing the many minds and forces which contribute to the success of a great building enterprise. It inspires to greater and greater effort to feel one's self impelled and guided to co-operation and emulation with many others in the creation of a landmark in the field of material progress.

If those who are associated in any of these works so characteristic of this age, learn to guide and be guided, to subordinate themselves to an important and difficult task, to harmonise their views and efforts with those of their co-labourers, then the creation of the skyscraper will have rendered a service to the professions of architecture and engineering far greater and more precious than the realisation of the financial forecasts made by the most sanguine projector and promoter of building enterprises.

TENDENCIES IN STEAM ENGINE DEVELOPMENT.

By James B. Stanwood.

IN discussing present tendencies in the development of the steam engine, it will be necessary to consider the conditions which have been, and are, affecting all types of engines; it is also necessary to consider special conditions which modify special types of engines or are producing new types. In well-known types there have been minor improvements dependent upon invention, discovery, and improved facilities which necessarily come within the range of the subject.

The most prominent condition affecting all engines, whether marine, locomotive, or stationary, is a more general employment of higher steam pressure. This increase of pressure has been marked within the last fifteen or twenty years. In marine practice it has risen in that time from 60 to 150 pounds, and, in exceptional cases recently, it has reached 270 pounds. In locomotive practice it has increased from 125 to nearly 200 pounds. In stationary practice 150 pounds are not uncommon, and 200 pounds are occasionally employed, although in that field 100 pounds are a ruling average. In the future this average will increase, as the more general introduction of water-tube boilers makes it practicable, and because it is a necessity if electrical apparatus is to be operated economically.

Multi-cylinder expansion engines have made it possible to use high steam pressure and secure its full benefits. Of these the marine engine has been, and is, the pioneer; in these engines, with 100 pounds pressure, steam usually expands through two cylinders; with from 135 to 175 pounds, through three cylinders; and with 200 pounds and over, through four cylinders. The cut-off is not earlier than half stroke, being nearly the same for each cylinder. The slide valve, or a modification of the slide valve principle, is invariably employed, and the late cut-off and the small range of expansion in each cylinder check cylinder condensation. A distinguishing feature of merchant marine practice is a uniform load and the absence of a governor for regulating speed.

In stationary practice, engines designed for uniform loads have usually a less number of cylinders and larger ratios of expansion than in marine practice. They are constructed with long strokes and perfected valve mechanism of the Corliss or some equivalent form, under the control of the governor cutting off between one-fourth and one-half stroke. A higher degree of expansion is obtained in each cylinder, but a greater proportion of cylinder condensation is induced than in engines of the marine type. On the other hand, mechanical losses between the cylinders are much less, and usually offset the increased loss by cylinder condensation. Thus, for instance, we find that two-cylinder compounds of this type are more economical than triple expansion marine engines. Engines of this type, compound and triple, have developed the highest economy on record.

The development of electricity is a powerful influence in producing new types and in modifying the old. It has exacted and is exacting very severe service of the steam engine. Designers are being forced to exert their greatest ingenuity in keeping pace with the ever-widening conditions which this useful agent dictates. This field creates the greatest demand for stationary engines,

and not only will there be a still greater demand in the future, but a greater variety of applications will be required.

The electric street railway represents to-day the most extensive development of electric power distribution, but it takes no very vivid imagination to picture the machine shop, the mill, the factory, and perhaps the present steam railroads all operated by the electric current.

As a means of producing light, electricity is universally employed. The requirements for its successful operation are fairly well understood. The work of an engine in an electric light plant, however, is extremely regular and uniform compared with that imposed upon the engine of a power plant. In the electric light plant the load may vary in amount as much as in the power plant; in the former there are, during every twenty-four hours, long periods of light load, but only one or two short periods of very heavy load. In the latter plant there may be a great many sudden and rapid sequences of light, moderate, or heavy loads for long or short intervals. There may be periods of no load, long periods of small load, short or occasional periods of excessively high load, and to all these severe fluctuations the engine must adjust itself. To design an engine to meet these demands is a problem which confronts the engineer of to-day.

First of all, close regulation is an important factor in such an engine. Remarkable improvements have been made in this direction in the past few years, especially in the construction and simplification of the main shaft governor, by the proper combination of inertia and centrifugal force; but these governnors have chiefly been applied to single valve automatic high-speed engines.

Such engines, directly connected to the generator, controlled by these governors, are now largely employed in electrical work for this severe service where the steam pressure is 100 pounds or less. They possess many valuable features; they are compact and simple, have a good range of power, and can be made to regulate very closely. On the other hand, these "mosquitoes" of engineering have a short, ephemeral life, are extravagant in the use of fuel, and maintenance and repairs are expensive. It is to be feared that those who use these direct-connected high-speed plants, will have to endure the same bitter experiences that are so familiar to the operators of the older type of high-speed belted plants.

The wider field for electric light and power demands a more economical type of engine, and if electrical distribution of power is ever to take the place of mechanical distribution, the engines must be as economical of fuel, if not more so, than those now usually employed, driving by means of belt and shaft.

Electric railway companies in large cities have felt the need of higher economy on account of the larger power that is required in their plants; the tendency now in their generating stations is toward higher steam pressure with horizontal tandem or cross-compound engines, condensing and non-condensing, direct connected to dynamos. The cylinder ratios are small, and bed plates, running gear and fly-wheels very large and heavy compared with the size of the cylinders employed.

A horizontal tandem or cross-compound engine usually has only two bearings for the shaft, which is of the side crank pattern; for large powers, it must be operated at a slow number of revolutions, as the bearings, necessarily limited to two, are very large, and the peripheral velocity of journal surfaces must not exceed reasonable limits, to correspond with the high bearing pressures employed. This form, if properly designed, is not liable to heat, as the bearings can be kept in line, and broken shafts and crank pins are almost impossible.

In horizontal or vertical engines, with two or more double-throw cranks, and three or more bearings, there is danger of imperfect alignment and a tendency to heat; there is also the possibility of breakage, which renders them somewhat undesirable. A horizontal engine is far more accessible for examination

and repairs than a vertical engine. It can usually be kept cleaner and freer from water and oil.

Where space is limited or extremely valuable, vertical engines of the marine type, with two or three double-throw cranks, have to be employed. It is probable that vertical engines can be operated more quietly at a higher speed and possess a higher mechanical efficiency than the horizontal engine.

In Great Britain the direct-connected unit has developed an engine of which the Willans may be taken as a type. These engines are vertical tandem compounds with the extremely short stroke of 6 inches or 8 inches, making 460 to 350 revolutions per minute for relatively high speed direct-connected dynamos. Most of these engines have very small clearances and are designed for high boiler pressures. Some are controlled by a throttling governor only; others have automatic variable cut-off gears. Some are single-acting, with a constant downward thrust, and some are double-acting. They all have enclosed crank cases with an extravagant amount of lubrication. A very large power is compressed into a very small space in these engines. When in good condition they operate very quietly. This type has not been generally introduced in America, but it possesses many points worthy of investigation and study by engineers.

The advantages which can be secured by a still further increase of boiler pressure than now employed, especially for engines with varying loads, is worth special consideration. The designers of compound locomotives and engines for the naval marine are face to face with this problem, although they are relieved of the condition of embodying in their engines a mechanism for close regulation,—the really difficult feature of stationary engine design.

Let us consider for a moment what the locomotive designer has to accomplish! He has to design a non-condensing engine which must exert its greatest effort (not power) in starting. It has to pull very light and enormously heavy loads, and it may be called upon to run at excessively high speeds as well as at great varieties of speed. For this purpose he has produced a non-condensing engine operating with nearly 200 pounds boiler pressure, cylinder ratio about 2 to 1, equipped with an intercepting valve to make starting possible. These engines have, with heavy loads, developed nearly 100 pounds mean effective pressure (referred to low pressure cylinder), while under ordinary conditions of load the mean effective pressure varies between 25 and 50 pounds.

Modern marine engines for the navy may be required to develop enormously large horse-powers for high speed in case of chase or flight. For long voyages, or cruising, a small horse-power only is required in order to prevent the extravagant use of coal. The latest practice in the British Navy, with 200 pounds boiler pressure, triple expansion condensing engines, ratio of high to low-pressure cylinder about 5.7 to 1, gives a maximum of 55 pounds mean effective pressure (referred to low-pressure cylinder) developing in two engines 25,000 horse-power. For cruising, when, say, only 5000 horse-power is required, a mean effective pressure of only 17 pounds (referred to low-pressure cylinder) is obtained, with about half speed and reduced boiler pressure.

Here are two instances which illustrate the manner in which condensing and non-condensing engines with high steam pressures are proportioned for great variations of load. It is probable that engines for direct connected generators, for similar variations, will have to follow the same line of development.

A great difficulty with engines of constant speed operating with very small mean effective pressures is the fact that these pressures are developed with a very low degree of economy. In condensing engines, 12 to 17 pounds is not extremely bad practice for light loads, but in non-condensing engines these mean effective pressures are too small. It follows, therefore, that if the light loads preponderate, the occasional heavy load should be carried by an extremely large mean effective pressure,

even though it is not so economical. In most electrical work the small loads predominate, so that high steam pressures and engines designed for large maximum loads, seem to be the only solution for economical operation.

This question of the relation between loads is one upon which the attention of the mechanical engineer must be critically bestowed. He must proportion the size of the cylinder so that the most suitable mean effective pressure shall be obtained for the ruling loads. The writer is of the opinion that engines that can develop a maximum power two, three or perhaps four times the usual working power will be in demand for power plants where great and sudden variations of load have to be dealt with. In the future, designers of steam engines will probably give closer attention to the methods of producing small mean effective pressures with the highest possible economy.

For the uninitiated, it is well to call attention to the relation existing between the mean effective pressure developed in the cylinder of a steam engine and the load imposed upon the engine. The horse-power of a given engine varies as the product of two factors,—the speed of the piston and the total mean effective pressure that can be obtained. In stationary practice the former is nearly constant in any given engine, as it is regulated within narrow limits by the governor; consequently, in a stationary engine the power will vary as the total mean effective pressure on the piston, which equals the mean effective pressure per square inch, multiplied by the area of the piston in square inches. Therefore, with a given area of piston the horse-power will vary as the mean effective pressure. The load is measured in horse powers, so that the mean effective pressure varies as the load.

For instance, a certain engine is lightly loaded; a small horse-power will carry this load. The governor adjusts the steam supply to produce the proper small mean effective pressure to give the required horse-power. If, on the other hand, a heavy load is thrown upon the engine, the governor admits more steam, producing a sufficiently larger mean effective pressure to develop horse-power enough to carry the heavier load. The mean effective pressure is thus the measure of the load in any engine. If 50 pounds mean effective pressure are sufficient to drive the maximum load of any engine, then 25 pounds mean effective pressure will drive one-half the maximum load, and 10 pounds one-fifth the maximum load.

Progress in the development of the well-known types has been varied. There is a general tendency toward higher piston speed, with slower rotative speeds for high-speed engines and higher rotative speeds for slow-speed engines. The worry, care, and expense of maintaining high-speed engines have brought them into disfavour for manufacturing purposes and they are used only where they are absolutely necessary.

On the other hand, there has been a reaction toward high speeds, as already pointed out, for direct-connected electrical work, which is the result of a compromise to bring the speeds of the engine and dynamo together. If we can judge by experience, the speeds of both the dynamo and the engine will be reduced in the future until a reasonable basis for durability, cost of operation and maintenance is reached. With long-stroke engines the speed has increased from 60 to 70 and from 70 to 90 revolutions per minute. There are some, with releasing gear, making 150 revolutions per minute. With these engines disc cranks are often used. As a consequence of increase of boiler pressure and piston speed, engines of a given size of cylinder, but with larger journals, crank pins, heavier bed plates and fly-wheels, are gradually receiving a higher rating. The prospects are that this process will gradually continue.

An important tendency of the times has been the cheapened cost of production due to standardising of details. The Corliss type of engine, for instance, has been most thoroughly treated in this manner. Every detail has been subject to the most careful study to secure the proper proportions and effi-

ciency, and to simplify the processes of manufacture, so that these engines are now built at wholesale instead of at retail. This same specialisation is true of automatic and slide-valve engines.

In regard to improvements in engine economy, engineers are beginning to see the advantages of reduced clearances and clearance surfaces. The highest economies have usually been obtained with long-stroke engines, in which these factors have been reduced to a minimum. It is along this line that designers in the future will be able to secure a better economy with early cut-offs, giving a greater ratio of expansion with small mean effective pressures. All these efforts are being made in order to reduce cylinder condensation.

Multiple-cylinder expansion contributes to this end by reducing in each cylinder the range of temperature and clearance losses. Small clearance surface contributes its share by reducing the amount of surface upon which condensation can take place. Another factor attracting attention which we may hear more of in the future is superheating; it is an old remedy resuscitated. It will probably be employed to do its part towards the suppression of the universal enemy,—cylinder condensation.

The question of lubrication is an important one, especially for high-speed engines. The enclosed crank case, already mentioned, is perhaps the simplest expedient for small engines. Continuous forced lubrication, however, seems to be necessary for the larger engines in which there are heavy bearing pressures and high speeds of rubbing surfaces.

With the increase of steam pressure and more extensive use of compound engines, the entire field of valve-gears is being carefully scrutinised. Valves which proved satisfactory with 80 pounds of steam pressure are failures with 125 or 150 pounds. Piston valves are largely employed, but not with any degree of satisfaction. The short-stroke gridiron valve is appearing again. Balanced valves of all sorts are being tried. It is difficult in the present state of the art to determine the most practicable form, especially where the valve has to be operated and controlled by a quick-acting governor.

Fly-wheel proportions are receiving attention from designers. The serious accidents which have accompanied increased speeds in large engines by the bursting of fly-wheels, due to poor design, material, or governor failure, have rendered this imperative. Instead of rule-of-thumb methods of design, the strains due to casting and centrifugal force are being investigated and provided for. Joints and fastenings of large, built-up fly-wheels are being strengthened.

Attention has already been called to the main shaft governor. The degree of close regulation that has been obtained, as well as the simplicity of the mechanism employed, is remarkable. There are governors on the market in which there are only one or two moving parts besides the spring, and yet the governor of the future for extremely high pressure, for compound or triple expansion engines, has not yet been fully developed. Where releasing valve-gears are employed with slow speeds, the problem is not so difficult.

Resuming, we find that higher steam pressure is affecting the proportions and designs of all engines. It helps economy, it gives more power, it permits greater fluctuations in load, and it enables large powers to be obtained from small compact engines.

Electricity is demanding a new engine,—one of good economy, and one that can adjust itself instantly to great and sudden variations of load. High steam pressure seems to be the means by which this can be secured.

In older and fixed types standardisation is reducing the cost of production. Improved and simple governors are giving better regulation. The horse-power obtained from a given size cylinder is gradually increasing on account of both higher piston speed and steam pressure, and as a consequence running gears are increasing in weight. High rotative speeds are not popular, though frequently necessary.

THE COTTON INDUSTRY IN INDIA.

By John Wallace.

SOME OF THE BOMBAY MILLS.

THE story of the manufacture of cotton in India belongs to two totally distinct periods, which, although they overlap, demand separate consideration. The first period has its beginning in those remote mythological ages when gods and men walked the earth together, and while we have no direct evidence to show that cotton was the first fibre used in Asia for the preparation of clothing, there is a strong probability that, on account of the ease with which it could be collected and prepared for manufacture, it was the first material to be spun and woven into cloth within the *habitat* of the cotton plant.

Mr. H. Lee, F. L. S., has given to the world a very careful study of the history of the cotton plant in "The Vegetable Lamb of Tartary," a book which contains a most interesting collection of fact and tradition that has in the course of ages grown around it. The earliest tradition is that of a tree in Scythia or Tartary, upon which grew seed pods, which, when they ripened and burst open, were seen to contain little lambs of whose soft white fleeces Eastern people wove material for their clothing. According to another version, a lamb of flesh and blood grew on the end of a stem, which was long enough to allow the animal to feed on the pasture around it.

Sir John Mandeville, according to Mr. Lee, was the first traveller to bring this story to England on his return from Eastern travel about the middle of the fourteenth century. Sir John claims not only to have seen, but also to have eaten of this lamb,—a story that was

quite in keeping with the taste and credulity of the time. He adds, in more credible vein:—"From that land men go towards the land of Bucharia, where are very evil and cruel people. In that land are trees that bear wool as though it were of sheep, whereby men make clothes and all things that are made of wool."

Cotton is mentioned by Nearchus, the admiral who brought the forces of Alexander the Great down the Indus, and who noted that "there were in India trees, bearing, as it were, flocks, or bunches of wool, and that the natives made of this wool garments of surpassing whiteness, or else their black complexions made the material whiter than any other."

Throughout the first period, and until quite recently, cotton was manufactured entirely by hand, and even at the present day hand spinning still exists in many parts of India, while hand-loom weaving, instead of dying out, has received, of late, a considerable impetus from the recent duties imposed in India on steam-woven cloths. It is worthy of note that modern machinery, while it has greatly cheapened the production of many kinds of yarn and cloth, has not exceeded in beauty and fineness the ancient products of Indian hand labour. Mr. T. N. Mukharji, in his "Art Manufactures of India," tells that two hundred years ago a piece of Dacca muslin, fifteen yards long by one yard wide, could be manufactured so fine as to weigh only 900 grains, or a little over two ounces. Its price was £40. He adds:—"The thread used for the best kind of muslins can, no doubt, be still spun by the women of Dhámráti, a village twenty miles north of Dacca, if they are sufficiently paid for their labour. Fifty rupees per ounce is not a heavy charge for such yarn. A piece of cloth, ten yards long by one yard wide, cannot be woven in less than five months, and the work can be carried on only during the rains, when the moisture in the air prevents the threads from breaking."

The chief difference by which the several qualities of Dacca muslin are distinguished consists in the number of threads in the warp; the finest qualities have 1800, the second, 1400, the threads being finer in proportion to their greater number. These fine qualities are distinguished by names such as *Sharbati* or "Sweet like Sherbet," *Shabwnam* or "Evening Dew," *Abrawán* or "Running Water."

While fine spinning by hand is gradually going out of vogue, hand-loom weaving with machine-made yarn still holds its own in many specialties which cannot be produced in the rapid working power-loom. This is particularly the case with goods having special fancy borders or ornamental ends into which gold, silk, and coloured threads are introduced. Certain goods are woven in

INDIAN MILL OPERATIVES.

power-looms, with gaps of bare warp at fixed intervals, which are afterwards filled in by the hand-loom weaver with the required finish, as, for instance, on the end of the *Junggree*, which, when wound around the head, becomes a turban.

The native hand-loom weaver requires a certain amount of open space in which to prepare and size his warps. This

BOMBAY COTTON MILL HANDS.

space in cities increases his rent, and, in such a city as Bombay, helps to reduce his very scanty earnings. Better times seem now to be in store for him through an invention which prepares his warps at the spinning mill, and enables him to buy them ready-sized and prepared for his loom at a less cost than if he prepared them himself. The first machinery for this object has already been ordered for a mill in the Bombany Presidency, and it is expected to increase profits on yarn spinning in mills that do not weave.

Closely allied with the hand spinner, the Indian cotton gin, known as the *churka*, is of unknown antiquity and of the rudest construction. It consists of a pair of rollers, of wood or iron, about fifteen inches long and from half an inch to two inches in diameter. At times they are geared together at one end; at other times each roller is driven separately from opposite ends as in the illustration on page 221. The rollers are one above the other and, in the words of an operative, the rollers "eat the cotton and spit out the seeds" which their small diameter prevents them from seizing. No other machine separates the cotton with so little damage; but it is the slowest of all gins. Twelve or fourteen pounds of cotton per day are considered good work.

Until the American Civil War in the sixties, cotton was packed in wooden screw presses to a density of 20 pounds per cubic foot and tied up with ropes. The screws were cut with a hammer and chisel out of the hardest available wood, and the nut was made in halves, of wood, and clamped together. Iron screws were next substituted, and numerous improvements followed one another in quick succession until to-day the Indian cotton bale, weighing 400 pounds, with a density about equal to that of water, is a model to the whole world. The hoops are continuous, and are not weakened anywhere by rivet holes. In damp weather a press, using water at a pressure of one ton per square inch, can turn out 32 bales per hour; but in dry weather, when the cotton is harsh and springy, only 28 bales per hour can be made, with water at one and three-quarter tons per inch in the rams. Air moistening has not yet been introduced into press houses in India.

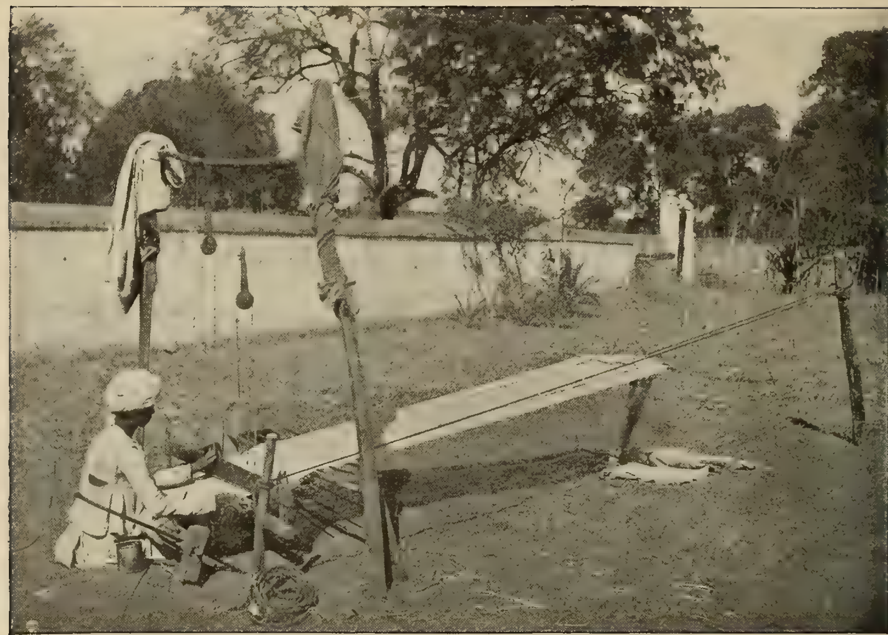
The introduction of steam and textile machinery into India was not a gradual process as in Western Europe, where it followed the successive improvements

of the pioneers of the present industry. On the contrary, the modern cotton mill came fully developed, was built from English models, and fitted, down to its smallest details, with English machinery and stores; and as there was no industrial population ready to "mind" the machinery, agricultural labourers were drawn from the fields to the mill by the inducement of good pay. This source has continued, until the present day, to furnish the bulk of Indian mill operatives. The conversion of a field hand into a mill hand is facilitated in India by the fact that the coarser qualities of yarn are spun at nearly all the mills. They average 20s., which are equal to 16,800 yards to the pound of cotton. The finest yarn spun in any Indian mill is 80s., or 67,200 yards per pound, and is made from Egyptian cotton, imported for the purpose.

The cultivation of cotton in India resembles that of no other country, and is an outcome of the organisation and traditions of the people. One would expect that a total crop of 2,200,000 bales, averaging 400 pounds in weight, would engage the attention of men of education and capital, as in America and Egypt. In India, howerver, cotton is produced by the poorest and least educated classes, who work on so small a scale as to permit the use of only the most primitive appliances. They give the minimum of manure, of water, and of labour to their crops,—everything deteriorates in their hands, and their chief merit seems to be that they can live in circumstances where other men would die. Their lives are frugal and laborious, but their "customs" demand extravagant festivals at marriages and funerals. They marry too young, with the most reckless disregard for means of subsistence, and their constant tendency is to overpopulate the land. Add to this a disposition to get into debt with its contingent expropriation, and the picture is complete.

It will be no matter for surprise, if, under these circumstances, the quality of Indian cotton should continue to deteriorate. The long staple varieties for which Guyerat was famous forty years ago are no longer to be had, and al-

PREPARING WARPS FOR THE HAND LOOM WEAVERS.



AN INDIAN HAND LOOM.

though the government has experimented for years at its model farms with a view to improving the mode of culture, no impression has been made on the native methods. This matter has for some years been the subject of appeal and warning from the *Indian Textile Journal* to the merchant and millowner, and recently Mr. I. M. Tata, a wealthy Parsee millowner, took the matter seriously in hand, and after visiting Egypt to study the method of cotton cultivation, he established experimental farms where long staple cotton is grown and irrigated in the manner that has proved so successful in Egypt. Should this venture prove successful, the culture of long staple cotton may, perhaps, attract the capital and intelligence which has made its success elsewhere, and may thus inaugurate a reform in agriculture that is most urgently needed in India.

According to official statements, the first cotton mill was started at Broach in 1851. Three years later the pioneer factory at Bombay was got to work by a Parsee, Mr. Cowasjee Nanabhoy Davar, with machinery from Messrs. Platt Bros., of Oldham, England. The mill had 20,000 mule spindles and proved a complete success under the title of the Bombay Spinning and Weaving Company. The building and its contents were, however, destroyed by fire in 1887.

There are now 148 cotton mills in India, with a total of 4,043,266 spindles and 37,021 looms, exclusive of handlooms, which have been estimated at 7,000,000. Bombay Island alone contains 67 mills, with 2,170,819 spindles, and 21,241 looms and employing 79,415 operatives.

The typical Indian mill is a plain three-story building for spinning, and a saw-roofed shed for weaving. In the interior of the country, where land is cheap, the whole building is a saw-roofed shed with a north light. This building, although cheap, has the disadvantage of being more affected by the changes of the weather than the storied mill. The fluctuations of temperature and of humidity are greater, rendering the cotton, at times, harsh and refractory in the dry season. This matter increases in importance as the spinning becomes finer, and it is complicated by

the necessities of ventilation, which tend to dessicate the cotton under treatment. When the relative humidity falls to 13 per cent., as it does at times in the interior, the development of electricity is so great in the machinery and belting as to render spinning almost impossible.

The great range of atmospheric humidity offers one of the chief difficulties of cotton manufacture in India. It varies from 13 to 98 per cent. Excessive moisture is met by warming the machines beyond the temperature of dew-point, and this often renders the mill too hot for the efficient working of the operatives. Several commissions have been held, and reports have been issued on the subject of mill ventilation, but as no properly qualified men were engaged on the work no good has resulted.

The owners of mills in India are men whose education has been purely commercial. With rare exceptions they have no scientific knowledge, and good profits are so easily made that they eschew experiments and avoid novelties. Their real talent is given to buying and selling.

An Indian cotton mill has rarely any architectural points of beauty. It is the cheapest building that will hold the machinery, and is more frequently than not a copy of some other mill, without inquiry into the defects of the model. This saves the charges of an architect, —a clear gain to the Indian owner. The mill operatives are Hindus or Mahomedans, the former predominating. These men, belonging mostly to the agricultural class, retain their interest in the land, and once in one or two years they leave the mill, for some months at a time, to return to the fields to which they devote their savings. Field labour is worth 2 annas a day,—roughly twopence,—while the mill pay amounts to 6 or 8 annas. But these men rarely remain at the mill after the age of forty. They return to die at their villages among their own people. This is one of the reasons why it is difficult to find hands for fine spinning. That is the vocation of a whole lifetime.

A NATIVE COTTON GIN.

PRINTING CALICO BY HAND.

Women and men work apart in the mill, the former being employed on reeling, with a forewoman in charge. They are very independent and prompt to take offense, and if their physical appearance and dress on a holiday may be taken as an index of their condition, they cannot be said to suffer from the effects of poverty or overwork. A short-sleeved jacket is their only sewn garment, and they are completely clothed in a *sari*, which they wind about them with great skill, and wear with a grace that is natural to them.

The children, up to the age of five or six, go completely naked, and the furniture of a house consists of a box or two to hold clothes and valuables, a rough bed frame, covered with yarn netting, and a few cooking pots of metal or earthenware. They eat no meat and feed with their fingers as the Apostles did, sitting on the ground.

A forewoman earns from Rs. 20 to 30 per month; a girl, Rs. 6 to 7; and a woman, about Rs. 8 per month. Among the men, the "minder" of a roving frame will earn from Rs. 12 to 15, the boys, from Rs. 6 to 7, and the weavers, from Rs. 13 to 16. An adult can live well on Rs. 5 for food, and his rent for a single room will not exceed Rs. 3 per month; but it frequently happens that as many as eight men will join in the tenancy of a room ten feet square, in which case their individual contribution for rent will be 6 annas per month. They buy their food cooked, they need no fire, and clothes are not needed for warmth, but rather for decoration.

The cheapness of Indian labour is counterbalanced by the extra number of hands required for a given production. About three times the number are needed in Bombay to do the work as compared with England. A love of

noisy amusement, a lack of concentration, and of ambition, and a partiality for holidays, with or without leave, are the faults of the Indian workman, who, as he may loaf and beg for months at a time, if the fancy comes on him, is a very difficult man to manage. Had he the industry and address of the Chinaman or the Japanese, it is possible that a large proportion of the Egyptian cotton crop would be spun in India with the aid of Indian coal.

In the early years of the cotton industry coarse yarns and grey cloths were the only products of the mills. Dyeing was then added, and fancy weaving followed soon after, along with hosiery, and, to a limited extent, small wares. Calico printing has been tried with indifferent success, but hand printing, with blocks, is an old industry that has been practised for ages all over India.

Fancy weaving in cotton, dyeing, and finishing (including glazing and the raising of naps) are all followed successfully in India, and aniline dyes, under the instruction of German experts, are rapidly superseding the traditional purple pigments. On account of the high price of coal in Bombay, most of it coming from England, the prime movers and boilers of the mills are kept in a very high state of efficiency. Compound engines are going out before the advance of triple, and even quadruple, expansion. High steam pressures are now the rule, and such is the completeness of the system of boiler inspection that explosions are practically unknown.

The future of the cotton industry in India is closely associated with a general improvement in the cultivation of the plant, until fine spinning can be maintained upon local staple. It seems also to involve a separation of the operative from agricultural pursuits which interfere seriously with his manual efficiency in the mill. This separation has actually begun in Bombay, Ahmedabad, and Broach, where some of the children of peasant operatives have ceased to have any interest in, or knowledge of, agriculture.

A third essential is the complete control of the mill atmosphere as regards humidity, temperature, and purity, so that they shall approximate in regularity to the other conditions of work, which have already been brought to a very high degree of uniformity.

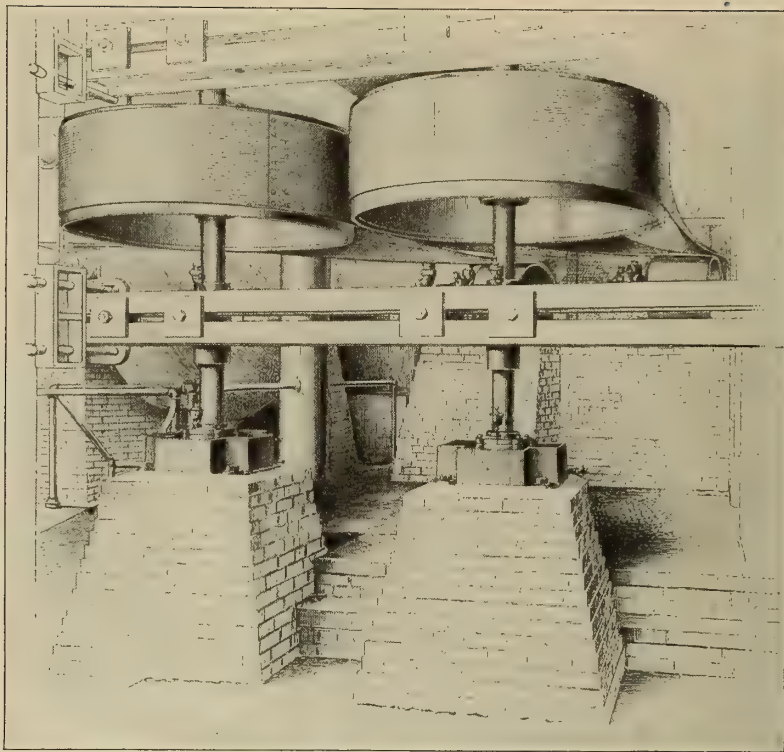
POWER TRANSMISSION BY VERTICAL SHAFTS.

By George V. Cresson.

ALL of the different methods of transmitting power, —by belting, ropes, vertical shafting, compressed air, water, or electricity,— have their value and their own special application. To know and apply intelligently the one best suited for each different place calls for the experienced transmission engineer. He must consider all the conditions and surroundings, the source from which the power may be obtained, and how and where it is to be used in the building under contemplation.

In high buildings, of from twelve to fourteen stories, common enough in the United States and devoted exclusively to manufacturing, with from five to fifty horse-power rented on each floor, vertical shafting has become a favourite means of transmission. The present system of such transmission was introduced into the United States by the writer in 1872, and since then its appreciation has been growing rapidly.

The old method of driving factories was by upright shafts connected by bevel gearing on each floor. This shafting was made of cast iron, very cumbersome and slow moving, and the constant trouble with the step bearings, the jar and noise of the gearing, and the



A VERTICAL SHAFT INSTALLATION.

difficulty of keeping gearing in line, all tended toward a change from this method, so that gradually the system of conveying the power to different floors by means of belting came into use. Where the belting is contained in a "belt tower," many of the dangers and objections incident to the belting passing through the floors and thus forming a connection from floor to floor, from basement to the top of the mill, were entirely removed. But in large cities the use of a belt tower is not admissible,—in most cases on account of the expense,—and naturally the tendency was to convey the power by belting directly through the rooms. The disadvantage and dangers of this system are, however, well known.

The writer's introduction of improved vertical power transmission into a power building in Philadelphia in 1872 was the direct result of a disastrous fire which started in the basement, near the belt holes, and was rapidly carried upward. In almost an instant each floor of the building was ablaze, hardly giving the operators on the different floors time to escape.

With belting running at a speed of from 4500 to 5000 feet per minute, the time required to convey a flame through a number of floors, is but a few seconds. In the case of many mill or factory fires that are read of, newspaper accounts abound with expressions of wonderment at the seeming mystery that the place was ablaze on each floor almost simultaneously with the first note of warning. There is, however, little mystery as to why the fire appears in each room of a mill at about the same time, and the experienced insurance men of to-day recognise this and have strongly urged the adoption of vertical shafts for transmitting the power. With these there is no objectionable connection of one floor to another.

Each tenant has his own power direct, and, when necessary, the power can be

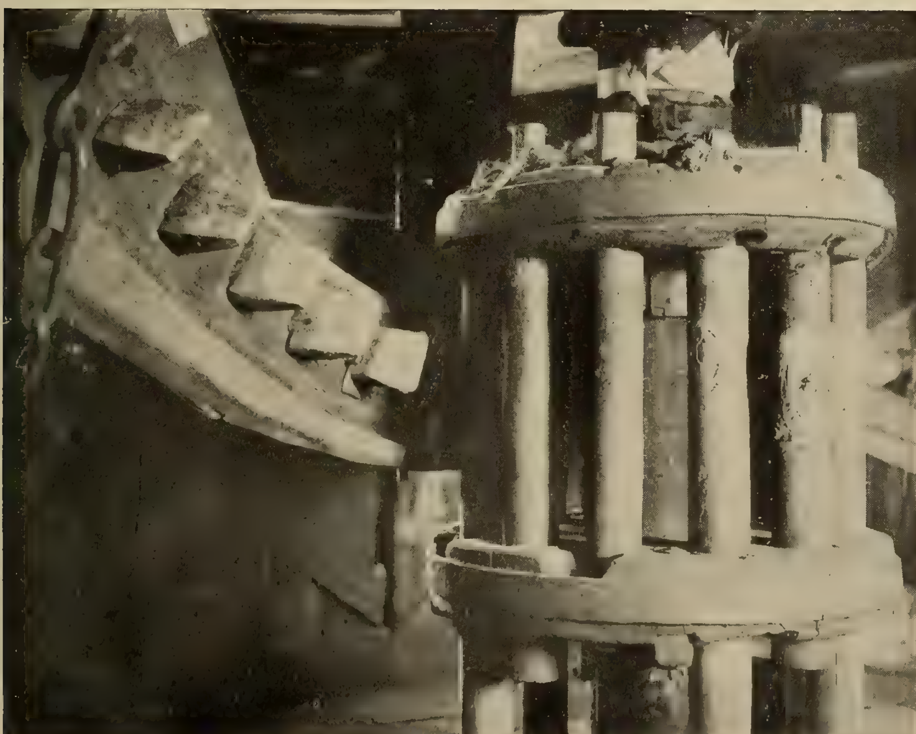
carried through an office, as it is absolutely noiseless in its operation. The loss of power, too, is very slight. A case recently tested, showed a friction load of only five horse-power for a 100 horse-power transmission. As to the cost of maintenance for repairs, it is interesting to note that the first installation that was made in 1872 is still running without alterations or repairs, and what is true in this case is equally so in scores of other buildings that have also been equipped in precisely the same manner.

AN OLD WINDMILL GEARING.

By C. W. Hunt.

A Note Presented to the American Society of Mechanical Engineers.

THE old windmill at Nantucket, Mass., was built in 1746,—one hundred and fifty-one years ago. It is of moderate size and in a good state of preservation, although it has not been operated for about twenty years. For about one hundred and thirty years it ran, and only terminated its work when modern milling methods made the small local mills unprofitable. The millstones are about 4½ feet in diameter, and the runner driven directly by the vertical shaft. The accompanying engraving shows the gear wheels,



A WINDMILL GEAR OF 1746.

which are typical of all the old types of windmills, both in Holland and America.

The face wheel is about 10 feet pitch diameter, with 6 arms and 62 teeth, 6 inches pitch. The lantern wheel is about 23 inches in diameter, with 12 rundles, each 3 inches in diameter. The teeth in the face wheel are old and well-worn, but the rundles in the lantern wheel are comparatively new; the injury to them shown in the picture was evidently caused a few years ago when the mill was started up to entertain tourists. Incompetent management soon caused such damage that it was finally shut down.

The rundles were accurately turned to fit the holes in the lower head of the lantern wheel. As the holes in the upper head are smaller and the rundles wore in service they were shoved up through the upper head and held by wooden pins over the upper head. The holes in the upper head are smaller than those in the lower, and the reduction in the size of the pins from time to time as they wore and were shoved up to a new position was crudely done, as the photograph shows.

The wooden strap brake for stopping the mill shows on the left and under side of the face wheel. The chain hanging down was used to chain the face wheel fast.

The heads of the lantern wheel and the vertical shaft show evident signs of great age, but no data were obtainable when the photograph was taken. The durability, however, of this type of wheels is very great.

In 1889 I visited a windmill in Holland with gearing similar to the Nantucket mill, which had been built sixty years before. The face wheel teeth were being renewed, and the owner informed me that the first set of teeth were replaced thirty years ago, and as these teeth had been in service thirty years, he was again renewing them, evidently considering the life of gear teeth as thirty years. They were also renewing the main shaft which had been in since the mill was built. The mill was used for grinding grain, and ran night and day, probably eighteen to twenty hours per day for the entire time. The gear teeth were greased with tallow.

The small wear of the teeth in service where the working pressure must be quite large for wood surfaces, may be accounted for by their elasticity. The teeth of the face of wheel and especially the long rundles of the lantern wheel are decidedly elastic, and when the pressure of the teeth is great, they spring enough from the geometric lines to prevent all sliding of the surfaces in contact during the time that the pressure is great. The sliding of the surfaces takes place only at the beginning and ending of the tooth action, when the pressure is comparatively light.

ELECTRO-CHEMISTRY AT NIAGARA FALLS.

By Frederick Overbury.

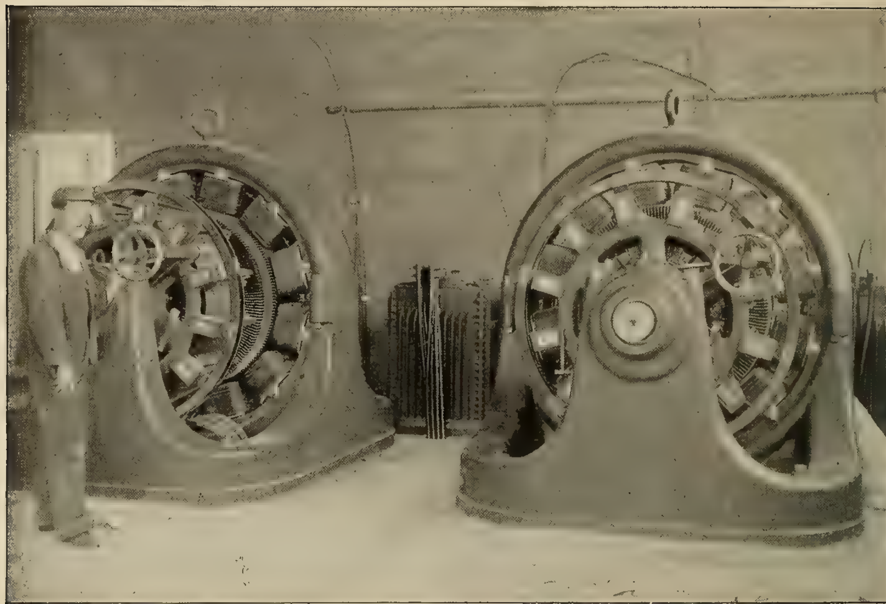
THE CHEMICAL CONSTRUCTION COMPANY'S FACTORY.

AN interesting development in the electro chemical line, much of which has been little written about, is now going on at Niagara Falls. Electro-chemistry, or properly electrolysis, was until recently a comparatively little understood science.

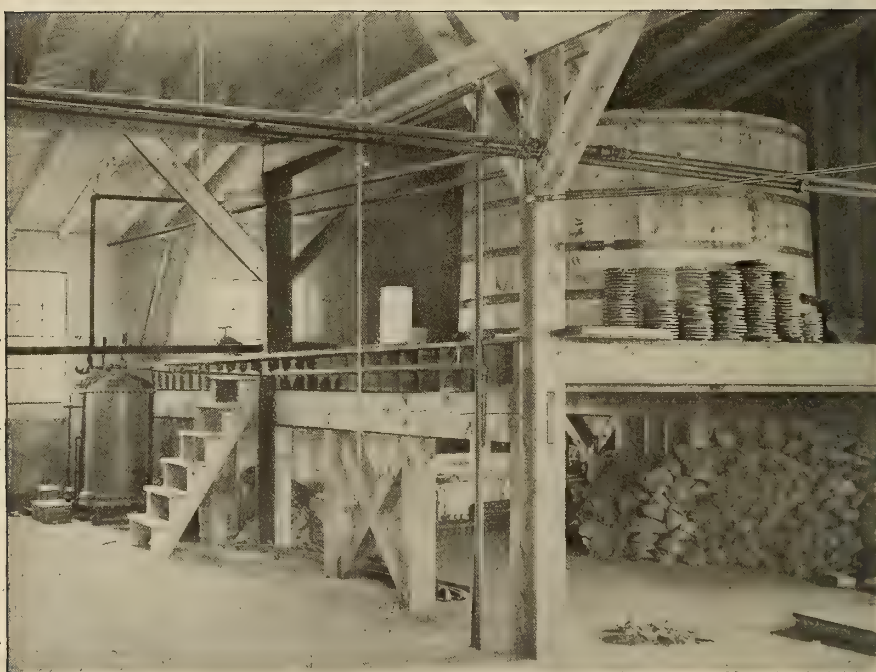
The greatest development has been made in Germany and France, and today large plants are profitably operated in those countries making a number of chemicals entirely by electrolysis. As one of the main expenses in electrical processes is the power, those plants which generate their electricity from a water fall have proved financially the most successful, and the Niagara Falls region, with its vast supply of cheap power, has therefore more recently attracted the attention of enterprise and capital in this branch of manufacture. To day the city of Niagara Falls has more factories making chemicals by electricity than any other city in the world.

One of the several interesting new works of this kind, located there, is that of the Chemical Construction Company, manufacturing chlorate of potash by a process patented by Henry Blumenberg. The uses of this product are constantly increasing. From five to six million pounds of chlorate of potash are imported annually into the United States. A large part of this amount is used in calico dyeing as an oxidiser. It is also used in making parlour matches, blasting powder and some of the smokeless powders. Medicinally it is taken, in the shape of pellets, for various ailments.

The Chemical Construction Company's plant is the first one to manufacture chlorate of potash in the United States, and as it thus marks the advent of a new industry there, it is not without special interest. The works are located on eight acres of land, leased from the Niagara Falls Power Company, and consist of three buildings, facing the Niagara river and connected by a side track with the Niagara Junction railroad. The main building is 165 feet long by 95 feet wide and has two



THE ROTARY TRANSFORMERS



THE STORAGE AND FILTER ROOM

stories; the second is the power station and boiler house; and the third is for storage and contains the dissolvers. The current is received from the Niagara Falls Power Company at 2200 volts, and by means of four static and two 250 horse-power rotary transformers, is brought down to 70 volts and about 5000 ampères. This is the lowest voltage used at the Falls. The company has contracted for 2500 additional horse-power to be delivered during this year.

The current is carried to a large switch on the second floor of the main building, on copper bars, four inches wide and half an inch thick. Thence it is distributed by the series system to the electrolytic tanks or cells, each one receiving a current of about 4 volts. This department is called the pot room, and is really the centre of interest in the plant.

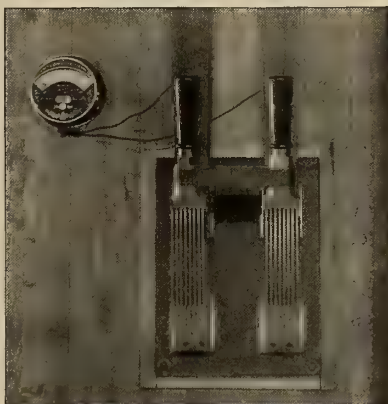
The first step in the process consists in dissolving, in large wooden tanks, from ten to twelve feet in diameter and six feet high, chloride of potash, commonly called muriate of potash. This salt is found in large quantities at Stassfurt, in Germany, and is shipped to the United States in bags containing 240 pounds.

The solution from the dissolvers is then pumped up to large storage tanks on the second floor of the main building, and from them is led through pipes by gravity to the electrolysing tanks. These are made of cast iron, porcelain-lined, about 8 feet long and 4 feet wide, and are divided by porous partitions into positive and negative compartments. The cells rest on pipe standards and are insulated from the floor, so that practically no current is lost.

The chloride solution is kept circulating through the cells from the positive to the negative compartments, and is electrolysed in its passage, evolving chlorine gas at the positive pole and forming caustic potash at the negative pole. The chlorine gas is led under pressure from the positive into the negative compartment, where it combines with the caustic potash, forming hypochlorite and chloride of potash. There is a considerable rise in the temperature of the solution during the operation, and the heat thus formed changes the unstable hypochlorite into chlorate and chloride of potash.

These chemical changes are very rapid and continuous, the arrangement of the cells requiring very little attention from the men in this part of the work. By suitable pipes the solution of chlorate and chloride of potash is led to the floor below, to large porcelain lined iron tanks containing lead steam coils, and is there evaporated down to the concentration point of chloride of potash when cold. From these tanks the concentrated liquor is run, boiling hot, into lead-lined wooden tanks where it is left to slowly cool.

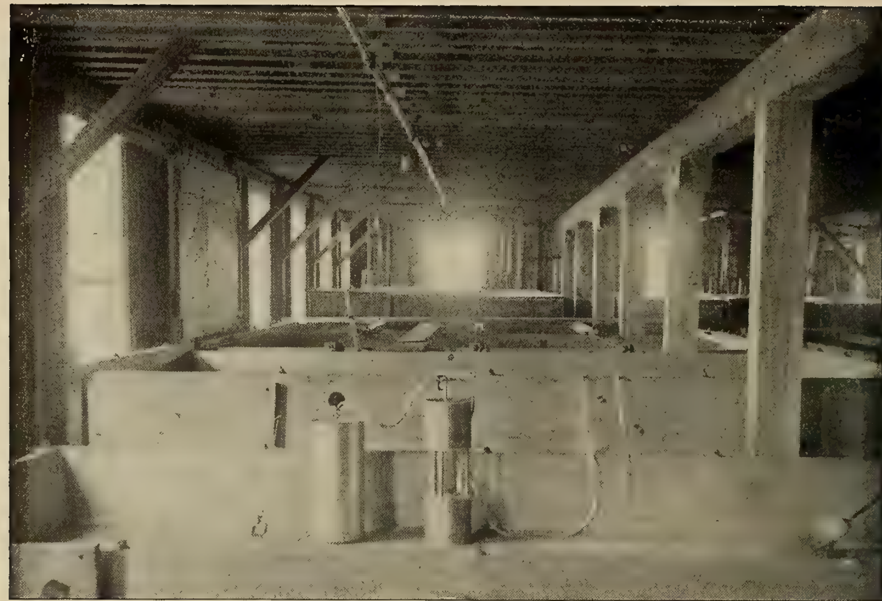
Any disturbance of the liquor at this



THE MAIN SWITCH.

period of the process results in breaking up the crystals into minute particles and hence great care is taken to keep it perfectly quiet. As the liquid slowly cools off, the chlorate crystals can be seen forming in square, flat shapes of different sizes. Very little of the chloride of potash in the solution is crystallised with the chlorate, as the two salts form at different densities.

After the crystals have all dropped to the bottom of the tanks, the mother liquor is pumped back to the storage tanks to be used over again in the cells. The chlorate crystals are gathered up with long wooden rakes, and conveyed to a centrifugal dryer. The moisture is



IN THE CRYSTALLISING ROOM.

here driven off and any chloride present is dissolved by spraying water into the dryer while in motion.

After this operation the crystals are loaded into a car and transferred to the dry room, where they are spread on shelves to more thoroughly dry before packing. This is the last operation in the process. The chlorate crystals are then delivered to the packing room and put up in kegs holding 100 pounds. The electrical processes differ from the old methods only in the chemical part of the work; the crystallising and drying are practically the same.

Every convenience for cheaply and quickly handling the solutions and finished product has been adopted and the plant will be enlarged to three times its present size before the end of the year. All the water used is supplied by the Niagara Falls Power Company from their filter plant, and is again filtered by the Chemical Construction Co. before using.

THE ROTARY ENGINE.

By Professor F. R. Hutton.

A Note Presented to the American Society of Mechanical Engineers.

ONE of the members has sent in an inquiry as to the position which ought to be taken by competent mechanical engineers on the general question of its being worth while for inventors to waste their time and thought in the pursuit of a satisfactory rotary engine. A recent work covering subjects of this general sort* has presented advantages and disadvantages of the rotary engine under the following heads:—

1. The effort of the steam is applied directly without intervening mechanism

* Mechanical Engineering of Power Plants. F. R. Hutton, 1897.

for conversion of the motion with their attendant friction, their costly fitting, and probable lost motion.

2. There being no reciprocating parts, there is no inertia to be overcome at the beginning of the stroke, with the attendant consumption of energy required to accelerate them.

3. The engine has no dead-centre, but will start from rest in any position.

4. Absence of reciprocating parts makes it easy to run the shaft at the highest speed. This has attracted designers of steam-driven dynamos to use this type of engine.

5. The engine becomes very compact from the absence of converting mechanism, so that it occupies very little room.

6. The engine has either no valve-gearing, or that which it has is of the simplest character.

7. These features, and the absence of expensive mechanism, make the engine cheap to build and therefore usually cheap to buy.

8. Absence of reciprocating rods and dead-centres results in a construction in which the presence of condensed steam in the cylinder does no harm. It does not stop the engine from turning, it cannot endanger the cylinder casting, the engine can be started, even if under water, by simply opening the value which admits pressure to it; it will start with solid water.

9. Its encased construction and the above peculiarities particularly adapt it for outdoor service and exposed places. Weather does it no harm, and its protection from outside injury makes it a serviceable quarry motor.

10. It requires no skill to handle. If constructed to be reversible, it can be reversed from a distance by simple rope and weight.

The objections to the rotary engine are both practical and inherent. The practical objections belong to the difficulty of satisfactorily packing surfaces which do not move through equal spaces in equal times. Those parts farther from the axis move through a longer path in a revolution than those nearer to the axis. The wear from abrasion is therefore greater at one part than another. When the packing-strips have become somewhat worn, leakage ensues, and a noisy rattle from looseness of the fits. A second practical difficulty is the expense connected with proper lubrication of such engines, and a difficulty of taking care of excess of oil rejected by the exhaust. If efficiently lubricated, they consume an excessive amount of oil.

The inherent objections to the rotary engine are:—

1. The presence, in the volume to be filled by live steam from the boiler, of an excessive waste space which has to be filled by steam at each revolution, which steam is exhausted without doing all the work there is in it. This corresponds in reciprocating engines to an excessive clearance.

2. The very continuity of the action of the steam upon the rotating pistons precludes the possibility with the single rotary engine of working the steam expansively, so that when the steam leaves the motor it shall have become largely reduced in temperature and pressure by doing work with increase of its initial volume. The expansion is from the boiler and the water in it, and not from the actual volume received by the engine for the work of one stroke. In other words, the rotary engine is a non-expansive engine. These two difficulties make the rotary engine uneconomical.

3. It is difficult to design the rotary engine for large horse-powers:—First, because the structure becomes inconvenient the moment that large areas are desired, so as to make a value of PA in the horse-power formula a large factor; second, because it becomes difficult to secure the condition of high piston speed in feet per minute unless the diameter of the casing be made so large that the difficulties both practical and inherent become nearly insurmountable and the advantages of the rotary principle are sacrificed.

The economy which a single rotary engine cannot secure from its inability to work the steam expansively has been sought and secured in a degree by arranging rotary engines in series upon a

shaft, so that the steam rejected from number one becomes the driving steam motor for number two of larger volume. By this means the steam when rejected is at more nearly the pressure and temperature of saturated steam at atmospheric pressure than can be attained with the single rotary engine.

In view of the existence of such disadvantages, both inherent and as yet unavoidable, how ought an engineer to meet the approach of inventors of rotary steam engines, if he wishes to retain a clear conscience and give sound advice? Have the words, "No Thoroughfare" been written over against the path towards a successful rotary engine?

MARINE ENGINE BEARINGS.

By John Dewrance.

Extracts from a paper read before the Institute of Marine Engineers.

THE following rule can be easily committed to memory, and is applicable to nearly all classes of bearing. Introduce the oil at the points of least pressure, and do not provide a means of escape for it at the points of greatest pressure. It is very easy to find out those points of an ordinary bearing that are least subject to pressure, and the oil can generally be brought there with a little scheming. The means of escape most generally met with are oil holes and channels that frequently occur just at the crown of the bearing, where the pressure is greatest.

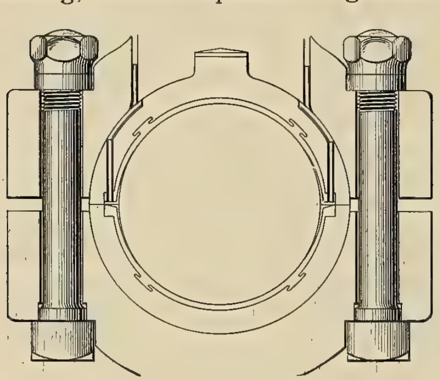


FIG. 1.

When the pressure on such a bearing is intermittent, the oil goes in when the pressure is taken off, and escapes again when the pressure comes on, the effect being that the bearing is able to support only a portion of the load that it could support if lubricated according to the rule. It is quite impossible to lubricate such a bearing at all, if subjected to a continuous load. Not a drop of oil will run down the hole at the crown of the bearing, and if oil is put on the shaft elsewhere, it runs out at the hole at the crown.

The accompanying diagrams represent the principal bearings of the marine engine to which this rule has been applied. Fig. 1 is the big end of the connecting rod of a vertical inverted marine engine. In this case the two sides are the points of least pressure, and, as will be seen, the oil is led to chambers at the sides. From these chambers suitable inclined planes are provided, and the oil will arrive at the surfaces which have to bear the load at a pressure per square inch equal to the load. It will be noticed that in each case the means of lubrication are in duplicate. This, in the case of large bearings, is strongly recommended, as otherwise one-half of the bearing only is lubricated by the oil that has passed through the other half, and in very large bearings this is not always found to be sufficient, especially when the bearings are new.

Fig. 2 represents the crank shaft bearings. The duty of these bearings is almost identical with that of the big end of the connecting rod. As will be seen, the lubrication is also the same. It seems to be very generally the custom to make these bearings hexagonal or

square on the outside. Such a bearing is very difficult to get out to examine or scrape up. The bearing shown is circular, and is prevented from turning with the shaft by a square part on the top half. Such a bearing can be taken out very readily.

Fig. 3 represents the little end of the

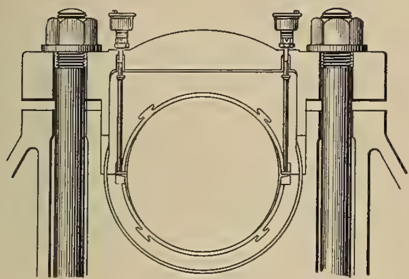


FIG. 2.

connecting rod. Here again the oil requires to be delivered to the sides the same as to the big end. The diagram shows the oil conducted through the pin. At the end there is a swivel joint. One of the pipes shown brings the oil for the little end and delivers it through

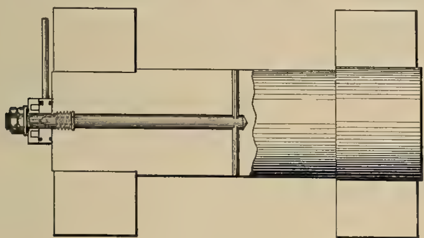


FIG. 3

the pin; the other pipe brings the oil for the big end and delivers it on the other side into a chamber, from which it is conducted by two pipes to both sides of the big end.

Fig. 4 shows the thrust block. It is strongly recommended that the cooling water should be kept away from the oil, as the mixture of water and oil is an inferior lubricant to pure oil. As will be seen, chambers are formed in the casting through which water can be circulated. There is a difficulty about this form of bearing, in that there is no point of least pressure at which to introduce the oil, so it is necessary to make one. To accomplish this the edges are sloped off as shown in Fig. 5. With inclined planes such as are shown, it is possible to draw the oil in between the surfaces up to any pressure.

If once we accept the principle set out in this paper it follows of necessity that a hot bearing is due to a failure of lubrication. If the oil is supplied, as shown by the diagrams, this may be due to the fact that the shaft is not round, is not running true, or else that it is not smooth enough. Shafts should be finished by clamps lined with emery cloth till they are well polished. Another cause may be that the bearings are not properly fitted. It is no light task to surface up a bearing so that the shaft beds thoroughly.

Having dealt with the subject of the means of lubrication, the next point is the oil. In these days of competition

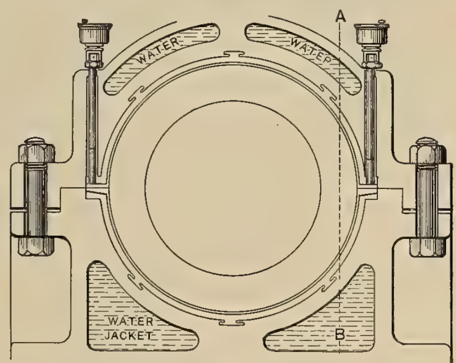


FIG. 4.

FIG. 5. SECTION ALONG *A B* IN FIG. 4.

and lowest tender, very inferior oils are sometimes used in very superior ships. Adulteration of oils is so general that

the names by which they used to be known have no longer any real meaning. Whenever it is possible it is the safest way to have the samples of oil examined and reported upon by a chemist, who also has the means of testing the lubricating properties.

Another very important point is the material of which the bearing is composed. Marine engineers seem to be very generally agreed that the bearing should be lined with one of the alloys known as the white metals. These may be divided into three classes. The first contains anything up to 80 per cent. of tin, the second anything up to 80 per cent. of zinc, and the third anything up to 80 per cent. of lead. If we could make sure of always using perfectly neutral oil, there would be very little to choose between these three classes; but in order to obtain a neutral oil, such as is prepared for clockmakers, the oil is agitated with zinc and lead shavings; a portion of each is converted into zinc or lead soap, which is afterwards separated from the oil. The principal impurity of lubricating oils is oleic acid, which rapidly corrodes lead and zinc. The effect then of using an alloy that contains a large proportion of lead or zinc is that the impurities of the oil combine with the surface of the bearing. Of course this may be avoided by using a very pure oil, but those that are responsible for the lining of the bearing are not always responsible for the quality of oil used, and even if they are at the time, they cannot make sure that they will always have it under their control. Tin is not affected by oleic acid or any of the impurities of oil, so the safest way is to use an alloy composed principally of tin, and containing only enough of the most suitable metals to harden it to the utmost. Many of the alloys at present used are too soft, and yield with a load of even as little as a quarter of a ton to the inch. Such a metal is liable to squeeze out in use. An all-round lining metal ought to stand at least five tons to the square inch without any yield; the best alloys will stand eight tons.

It is a very general custom among marine engineers to hammer the alloy after the bearing is lined. If the alloy is as hard as is desirable it cannot be very ductile, and this hammering cracks it in all directions; if, on the other hand, the alloy is ductile enough to stand hammering, it is conclusive proof that it has too low a compression test to be suitable for lining marine bearings. The points dealt with are no untried ideas, but are the result of many years of study of the subject, and a very long series of experiments.

WILLIAM LAIRD.

A Biographical Sketch.

BIRKENHEAD, opposite Liverpool, is to many, perhaps, less well known than the great shipyard of Messrs. Laird Bros., which it harbours, and of which the guiding spirit is Mr. William Laird. Whether considered as a man of business or as a public benefactor, he must be recognised as one who has succeeded in life, not through patient acquiescence and by diligent waiting, but rather through sheer energy and personal activity.

The establishment of the superiority of iron over wood for shipbuilding purposes was, undoubtedly, one result of Messrs. William Laird & Son's spirited experiments in the years from 1830 to 1835 (the firm was then represented by the grandfather and the father of Mr. William Laird), when, despite popular opposition, they successfully constructed six vessels of iron. Since that time the firm has gone on enlarging its operations, and has designed and constructed over six hundred vessels, and earned a world-wide reputation.

In earlier years they took the lead in

introducing iron as the material for a great variety of vessels for river and channel navigation, including mail steamers for home and foreign service, among them the Holyhead and Kingston Irish mail boats. For over fifty years they have constructed transatlantic and other mail and passenger steamers and war vessels of many types for British and foreign navies, and are even now in the front rank with their two first-class British battleships *Royal Oak* and *Mars*, each of about 15,000 tons, and innumerable torpedo boat destroyers of very high speeds.

THE BRITISH BATTLE SHIP "MARS" COMPLETING FOR SEA AT MESSRS. LAIRD BROS.' FITTING-OUT WHARF, BIRKENHEAD.

With all this, the subject of this memoir, before and since his father, John Laird, became member of Parliament, has been closely associated, together with his brothers,—John, still his partner, and Henry H., lately deceased—under the firm name of Laird Bros. Mr. Laird is of Scotch extraction, his father having been born in Greenock in 1805; his mother came of the English family of Hurry, and was born in Liverpool. On the completion of his education at Harrow, he became associated with his father at Birkenhead.

He is a member of the Institution of Naval Architects and also of the Institution of Mechanical Engineers, as well as a member of the Council of the latter. Three times he has been elected Mayor of Birkenhead, and is a Justice of the Peace for the county and borough. He has also been formally asked to represent the borough in Parliament, but in spite of the numerous attractions which such a prospect must necessarily have presented to so gifted and able a man, he declined, stating that his reason for so doing lay in the fact that he was a partner in the firm of Messrs. Laird Bros., which held Government contracts.

In 1864, Mr. Laird was elected a Birkenhead Commissioner, and upon the incorporation of the borough he was nominated as a Town Councillor for Argyle Ward. Since then he has uninterruptedly served the borough as a member of the Town Council.

In Mr. Laird, Birkenhead has found an ardent and energetic supporter and promoter of church building and church extension. It was through his benevolent and philanthropic action and example that St. Peter's and St. Luke's were reared, and with the latter in particular he proved generous and open handed, for, in addition to giving large sums to the general fund, he contributed

to numerous special objects, such as the cost of building the chancel, which entailed the munificent gift of over £5000. Mr. Laird's name will also be long remembered in connection with the extension, in 1880, of the Borough Hospital, founded by his father, John Laird, M. P., in 1863. This now affords accommodation for at least fifty in-patients, and is provided with the best arrangements for surgical attendance and nursing that modern skill and science can supply.

While chairman of the School Extension Committee in 1882, Mr. Laird was largely instrumental in raising, by means of voluntary subscriptions, between £15,000 and £16,000, which large sum was devoted to enlarging existing schools and building new ones.

In his younger days Mr. Laird also found time to assist in the volunteer movement, and on the formation of the first Cheshire Rifle Corps he joined this regiment as a private, and, in consequence of having successfully attended the first musketry class of volunteers held at Hythe, acted as musketry instructor to the corps until the formation of the Fifth Cheshire Artillery Volunteers, of which he was gazetted captain, ultimately attaining the rank of major of the brigade, which he held for upwards of ten years.

Current Topics.

THE advent of important and valuable inventions is often dependent, not upon the brilliant inspiration of some individual inventor, but upon the general and gradual advance of the state of the art to which they belong, making their occurrence not only possible, but almost inevitable. The bicycle is an excellent example of this kind of growth in mechanical construction, since, while it is one of the most important things, both mechanically and commercially, which has ever been produced, it owes its development to the parallel improvements in metal and rubber working without which it could never have existed at all, in the modern sense, or to any extent. The clumsy wooden velocipede would always have remained a useless toy, had not the introduction of drawn steel tubing made the construction of a light, and yet strong, frame possible, while the original leather tire of Dunlop could never have led to the practical application of the pneumatic principle without the substitution of the rubber construc-

tion which only the advances in rubber manufacture made possible. This is but one instance of what is apparent in many other lines of work, and there is little doubt that if the patent records of the past fifty years were thoroughly studied by competent specialists, many inventions, which at the time of their conception were failures, simply because of the impossibility of executing the ideas, would now be found both practicable and valuable.

It is unfortunate that in the building up of the United States navy there has, apparently, been no definite policy and scarcely any of the ships are exactly alike. The necessity of having identical ships in war time cannot be overestimated. In the first place the speed of any fleet is the speed of the slowest ship in it. If, therefore, one battleship can make only 15 knots, while another can make 16, the speed of the fleet must be 15 knots. The advisability of having ships built similarly, so that, after battle, the crippling of several ships may throw out of use only one on account of the interchangeability of parts is apparent. This is especially desirable in the case of the machinery, though it may be said, with some show of reason, that the navy of the United States is only in its beginnings, and that on that account restriction to a few designs would not have been a wise policy, as this would have taken away the opportunity of ultimately arriving at the best from experience with all types. The greatest diversity of designs is probably noticeable in the case of the torpedo boats. The machinery in these may be said to bear the same relation to the machinery of, say, a battleship, that the works of a watch do to those of a clock, and it is this comparatively greater delicacy which leads to greater likelihood of accident. Interchangeability of parts of these boats is, therefore, a special desideratum.

Hand in hand with the determination of rebuilding the American navy goes the desire to build up American shipbuilding interests. This desire, in a measure, justifies a policy, in letting contracts, of allowing each contractor to introduce his own ideas. Once the experimental stage is passed in this work, however, it would be well to require that in the building of a lot of torpedo boats, there should always be a certain number exactly alike, all parts being interchangeable. Every engineer will appreciate the desirability of some such course, but every layman even will be surprised to learn that some government work has been accepted in which there is scarcely a screw thread that is standard. It was supposed that the battleships lately contracted for by the United States would all be similar; but this is not the case. Nos. 5 and 6, known as the *Kentucky* and *Kearsarge*, are alike, and Nos. 7, 8 and 9, are alike, but differ from Nos. 5 and 6. A step was made in the right direction when it was concluded to place in Nos. 7, 8 and 9 the same design of engine used in Nos. 5 and 6. There is a difference in the boilers, but this is of little moment as in boilers, unless of certain water-tube types, parts are not interchangeable.

The difference in the arrangement of turrets of these battleships has perhaps attracted more attention than anything else concerning them. This is because of the innovation of placing on Nos. 5 and 6 what have become known as two-story turrets. This plan has been severely criticised, and, probably as a consequence, it has not been adopted on battleships Nos. 7, 8 and 9, which will have one-story turrets, each containing two 13 inch guns. In the two-story design, each lower turret, or first story, contains two 13-inch guns, and each superposed smaller turret, two 8-inch guns. The large and small turret being practically one, the disabling of the turret turning gear would throw out of use four guns. Then, too, the fire cannot be divided. Those favouring the design claimed that the chances of disabling the turret turning gear were reduced with only one, and that a divis-

ion of fire is not desirable and not good tactics. A very forcible argument in favour of the plan was that it saved 35 tons, or more, in weight. A scheme which had been proposed, instead of the two-story plan, was to place the 8-inch guns in independent turrets, one abaft the forward large turret, and the other forward of the after large turret, and both at same elevation as when placed on top of the large turrets. An all-around fire would thus be insured, but the fore-and-aft fire would probably have to be dispensed with on account of the concussion endangering the lives of the crew in the large turrets over which the shots would pass.

SOMETIMES the progress of improvement is retarded by a conservatism which is due rather to a reverence for precedence and authority than to a caution borne of intelligent opinion. For over forty years the great steamers struggled across the ocean under steam pressures not higher than twenty or thirty pounds per square inch, fully one-half the work in the engines being due to the action of the vacuum, when there was really nothing to have prevented the use of pressures as high, and engines as efficient, as those now in use, except the overpowering influence of the opinion of James Watt. Oliver Evans and Jacob Perkins both showed the possibility and advantage of high-pressure steam. Both fearlessly used pressures of from 150 to 500 pounds and over, while Hornblower and Woolf demonstrated the economy of multiple expansion beyond doubt, before the beginning of this century. The great authority of Watt, however, pronounced high pressures most dangerous, and compounding useless, and the two greatest improvements which have been made in the steam engine since its first inception were retarded more than half a century by his unsupported dictum. It by no means follows that authority is to be brushed aside, and the experience and opinions of great and successful engineers neglected, but it should at least be demanded that the influence of genuine conservatism be not exerted in the lines of suppression and obstruction. The giants of engineering and science should remember the old saying that "a dwarf upon the shoulders of a giant may sometimes see farther than the giant himself."

ALREADY the economy of internal combustion engines, whether operated with gas or with volatile hydrocarbons, is much greater than that of the steam engine and its inevitable boiler, and the lines along which gas engine improvement must be made are fairly well marked out. Of the energy contained in the gas, from 20 to 25 per cent. is now converted into effective form, the remainder being carried off with the cooling water, or rejected with the discharge gases, or in radiation. The most recent tests have shown the effective conversion of over 30 per cent. of the energy, most of this gain being from a reduction in the amount of heat rejected with the cooling water, and it is evident that a still greater economy could be attained if mechanical difficulties, such as cylinder wear, lubrication, etc., did not forbid, for the present, the use of higher cylinder temperatures. That such higher temperatures may soon be made practicable, either by improved methods of lubrication or modifications in construction, it is most reasonable to expect; and when the same united efforts that have been made by engineers all over the world for the improvement of the steam engine, are given to the extension of the limits of temperature of the gas engine, there is small reason to doubt that we shall begin to realise an economy in the combustion of coal of which we need not be ashamed. It is to this subject, almost as much as to the direct generation of electrical energy from coal, that engineers, physicists and chemists should lend their efforts, for it matters little in what form the energy is developed if only the wastes be reduced; and when to improvements in the motors developments in the production of fuel gas from grades of fuel at

present useless, are added, some conception of the possible commercial economies may be obtained.

THE various effects of the transformation of energy are sometimes most interesting, appearing when least expected. Most machinists know that many of the steel tools used in a shop, such as drills, chisels, taps and the like, become slightly magnetised by use, and will pick up small fringes of iron filings, and this effect has been reproduced intentionally by holding a steel bar in the direction of the dipping needle, and striking repeated blows with a hammer upon one end of the bar. The vibrations caused in the particles of the steel are supposed to permit the rearrangement of the molecules according to the polarity induced by the magnetism of the earth, and the bar after a short time is found to be slightly magnetised. A much more striking effect has recently been observed in a tube mill containing a number of hydraulic drawing benches for the manufacture of drawn steel tubing for bicycle construction. Quite accidentally these benches were placed in a north and south line, with the result that the tubes, after drawing, were found to be strongly magnetic, whereas before this operation little or no magnetism was observed. The preliminary tube drawings are made in vertical machines, and although no comparative observations have been made upon horizontal benches at right angles to the magnetic meridian, it seems altogether probable that little if any magnetism would be developed in that position.

THE theory of evolution has been applied to the mechanical as well as the animal world, and it is sometimes quite possible to trace the descent of a piece of machinery from various details of its construciton. Thus many of the earlier woodworking machines were built upon wooden frames, and when iron frames were substituted, the lines of the wooden construction were followed for a long time, although quite unsuited to the changed material. Similarly when railroads were first started in England, the carriages for personal transportation were constructed by making a long body frame, mounted upon trucks, and placing on it three stage-coach bodies, all being well bolted together. The travelling public was thus given accommodations which, in interior arrangements at least, resembled very closely those to which they had been accustomed, and after some demurring the new order of things was gradually accepted. As the art of car building progressed, however, it was soon found much better to construct the whole affair as one piece of work, but the influence of custom was so strong that the British railway carriage is stil l built on the stage-coach model, and it is to this cause, rather than to any other, that the compartment system owes its being. Although the carriage is practically built as one vehicle, it is ornamented on the outside by mouldings, curved to follow the old lines of the stage-coach body, and even when these mouldings are omitted in the lower class carriages, curved stripes of paint are put on to tell the story of the evolution of the car from the coach.

BUT there are other examples of the absurdity of imitating in form a construction of which the need no longer exists. The motor carriage is already in evidence, and it, too, bears the ear marks of its horsy, though horseless, origin. One of the latest forms of these carriages bears all over indications of the existence of the horse that isn't there. In front there is a high leather dash board to protect the riders against the splashing from the heels of the absent animal, while the finish of the heavy trimmings could only have emanated from the establishment of a builder of carriages made for horses, and the whole vehicle looks as if it ought to have a pair of lively animals in front of it to make it look complete. It is, indeed, difficult to get rid of old ideas even when the necessity of their

presence is absent; but the mental inertia which makes such things possible, is probably inherent in human nature, and its elimination requires a long course of education and experience.

DOUBLE bottoms are among the most radical improvements made in later years in the structure of iron and steel ships. Not only do they effectively provide against danger from rents in the outer plating, preventing ingress of water to the body of the ship, but they add materially to the strength of the lower parts by admitting of better disposition of structural material. Another advantage of double bottoms is the ease with which they lend themselves to the purpose of ballasting. A large vacant space in a vessel's bottom would be detrimental to her stability, as it would act on the principle of an air vessel, and tend to capsize her, but if the space between the two skins of the ship be filled with water, an opposite tendency to that just mentioned would be brought into action, and the normal stability of the ship would be increased. The double bottom would become a source of economy to the shipowner, in that he could ballast his ship at the least possible cost, and make all her cargo-carrying capacity freight earning.

THE value of an inner bottom in vessels of war has been crucially tested during the past few years, and many instances might be cited in which it has been the salvation of the ship and proved beyond doubt that had no inner bottom existed very grave results would have followed. In the mercantile marine numerous cases, too, are on record of the usefulness of an inner skin, notably that of the historical *Great Eastern*, the prototype of the cellular system of construction. Several times she struck on sunken rocks, and on one occasion ran ashore and tore a hole 80 feet long in her outer plating. The inner skin, however, remained intact and prevented further damage.

THE origin of the words "starboard" and "larboard," as used in the nautical vocabulary, has been attributed to the Italian words *questa borda*, meaning "this side," and *quella borda*, "that side." Abbreviated, these two phrases appear as *sta borda* and *la borda*, and by corruption of languages were soon rendered "starboard" and "larboard" by British sailors. These two words sound so much alike that frequent errors and accidents occurred, and years ago, therefore, the use of "larboard" was discontinued, and "port" was substituted.

READY FOR LAUNCHING.

LAKE STEAMER SENATOR.

CAR FERRY STEAMER SAINTE MARIE, PASSING THROUGH 36 INCHES OF ICE.

Built by the DETROIT DRY DOCK CO.

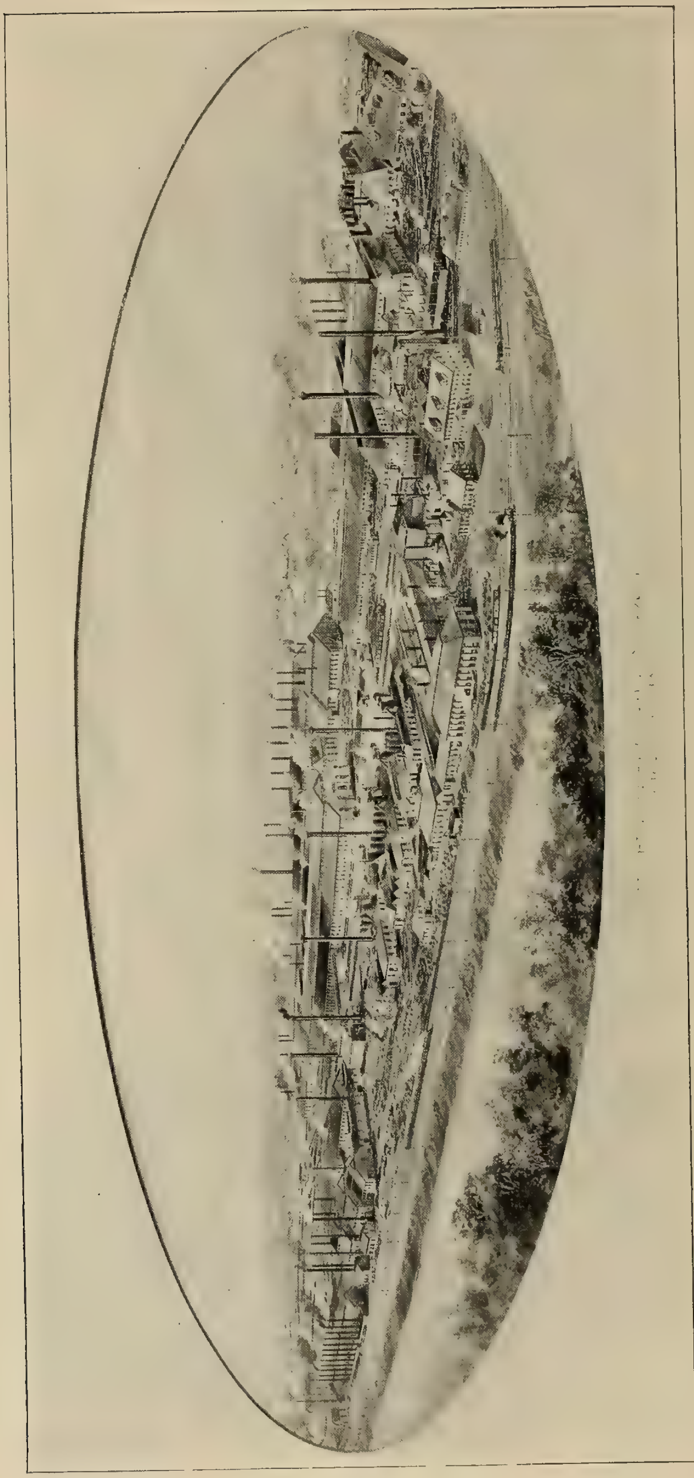
Alphabetical Index to Advertisers.

Cassier's Magazine, published monthly, $3.00 per year. Entered at the New York Post-Office as second-class matter.

Cassier's Magazine—Marine Number.

AUGUST, 1897.

CONTENTS—Continued.



WORKS OF THE BETHLEHEM IRON COMPANY, BETHLEHEM PA.

AT WHICH ARE PRODUCED:

Armor Plate.
Billets (1½ in. up). Blooms, Slabs, Coke.
Ferro Manganese, Spiegel-eisen, Pig Iron.
Forgings, such as Axles, Arch Bars, Links, Pins and other Car Forgings, Connecting Rods, Crank Shafts, Locomotive Frames, Eye Bars.
Plates for Boilers, Bridges, Ships and Tanks.
Rails, Steel, 16 to 100 lbs. per yd.: Steel Splice Bars (plain and angle), for all sections of Rails.
Rolled Structural Shapes, such as Angles, Rounds, Flats, Squares, Ovals, I-Beams, Channels, Bulb Angles, Deck Beams, Tees, Zees, etc.
Structural Work, such as Bridges, Buildings, Elevated Railroads, Girders, Columns, etc.

ADDRESS:

GENERAL OFFICES:

Pittsburg: Carnegie Building.

SALES OFFICES:

Atlanta: Equitable Building.
Boston: Telephone Building.
Buffalo: German Insurance Building.
Chicago: Marquette Building.
Cincinnati: Neave Building.
Cleveland: Perry-Payne Building.
Denver: People's Bank Building.
Detroit: Hammond Building.
London (Eng.): 47 Victoria Street.
Minneapolis: Guaranty Loan Building.
Montreal: 3 Windsor Hotel.
New York: Bank of America Building.
Philadelphia: Harrison Building.
St. Louis: Globe-Democrat Building.
San Francisco: 258 Market St.
Washington: National Safe Deposit Building.

The Works owned and operated by

THE CARNEGIE STEEL COMPANY, LIMITED,

are as follows:

BLAST FURNACES.

EDGAR THOMSON FURNACES, at Bessemer, two miles from Pittsburg, on the Pennsylvania, the Baltimore & Ohio, the Pittsburg & Lake Erie, the Pittsburg, Bessemer & Lake Erie, and the Union Railroads, and the Monongahela River. Nine stacks. Product: Bessemer Pig Iron Spiegel-eisen and Ferro Manganese. Annual capacity, 1,000,000 gross tons.

DUQUESNE FURNACES, at Duquesne, four miles from Pittsburg, on the Pennsylvania and the Union Railroads, and the Monongahela River. Four stacks. Product, Bessemer Pig Iron. Annual capacity, 800,000 gross tons.

LUCY FURNACES, at Fifty-first Street, Pittsburg, on the Allegheny Valley Railroad. Two stacks. Product, Bessemer, Forge and Foundry Pig Iron. Annual capacity, 200,000 gross tons.

STEEL WORKS.

EDGAR THOMSON STEEL WORKS, at Bessemer, two miles from Pittsburg, on the Pennsylvania, the Baltimore & Ohio, the Pittsburg & Lake Erie, the Pittsburg, Bessemer & Lake Erie, and the Union Railroads, and the Monongahela River. Four 15 gross ton Bessemer Converters. Product: Bessemer Steel Rails and Billets, and Iron and Brass Castings. Annual capacity, 1,000,000 gross tons of Steel Ingots, and 50,000 tons Castings.

DUQUESNE STEEL WORKS, at Duquesne, four miles from Pittsburg, on the Pennsylvania and the Union Railroads, and the Monongahela River. Two 10 gross ton Bessemer Converters. Product: Rails, Billets and Splice Bars. Annual capacity, 450,000 gross tons of Steel Ingots.

HOMESTEAD STEEL WORKS, at Munhall, one mile from Pittsburg, on the Pennsylvania, the Pittsburg & Lake Erie, and the Union Railroads, and the Monongahela River. Two 10 gross ton Bessemer Converters; twenty Open Hearth Furnaces. Product: Blooms, Billets, Structural Shapes, Bridge Steel, and Armor Plate, Ship and Tank Plate, and Steel Castings. Annual capacity: 400,000 gross tons of Bessemer Steel Ingots and 500,000 tons of Open Hearth Steel Ingots. Finishing capacity of Armor Plate Department, 10,000 gross tons per annum.

ROLLING MILLS.

UPPER UNION MILLS, at Thirty-third Street, Pittsburg, on the Allegheny Valley Railroad. Product: Structural Steel, Steel Bars and Steel Universal Mill Plates. Annual capacity, 140,000 gross tons.

LOWER UNION MILLS, at Twenty-ninth Street, Pittsburg, on the Allegheny Valley Railroad. Product: Universal Mill Plates, Car Forgings, Bridge Work, Angles, Axles, Links, Pins and Bar Steel. Annual capacity, 65,000 gross tons.

BRIDGE WORKS.

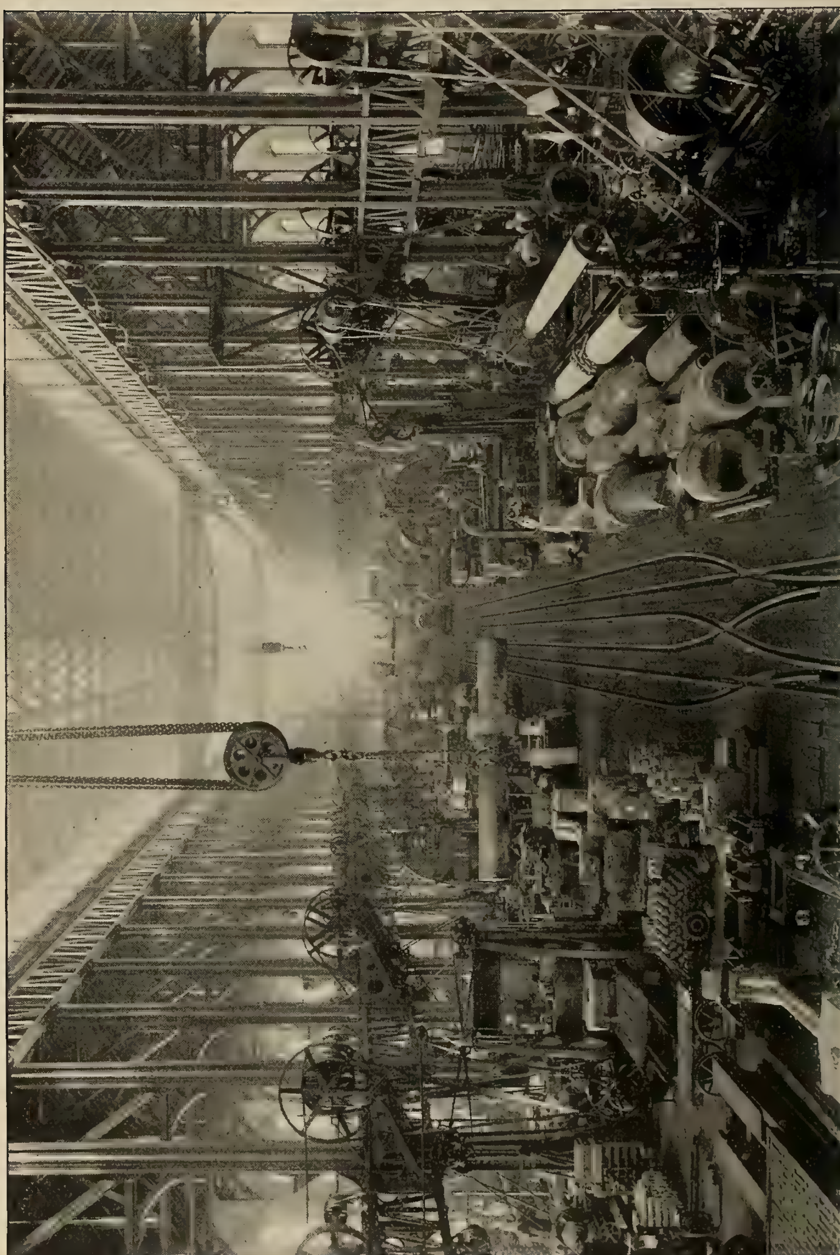
KEYSTONE BRIDGE WORKS, at Fifty-first Street, Pittsburg, on the Allegheny Valley Railroad. Product: Steel Bridges, especially for Railroads, Elevated Railway Structures, and Steel Frames for Modern Office Buildings. Annual capacity, 50,000 gross tons.

To Foreign Governments.

Through William Cramp & Sons' S. and E. B. Co., Philadelphia, Pa.
Forgings for Japanese Cruiser *Kasagi.*
Through Union Iron Works, San Francisco, Cal.
Forgings for Japanese Cruiser *Chitose.*
Through Takata & Co., Tokio, Japan.
Forgings for Japanese Cruiser.

To Private Concerns.

Through William Cramp & Sons' S. & E. B. Co., Philadelphia, Pa.
Forgings for—
International Navigation Co., S.S. *St. Louis* and *St. Paul.*
Panama R. R. Co., S.S. *Advance* and *Finance.*
Wm. P. Clyde Co., S. *Comanche.*
B. C. and R. S. S. Co., S. *Atlanta.*
Through Atlantic Works, Boston, Mass.
Forgings for Boston Fruit Company's S. *Bernard.*
Through Neafie & Levy, Philadelphia, Pa.
Forgings for Boston Fruit Company's S. *Bernard.*
Through Consolidated Iron Works, New York, N. Y.
Forgings for North German Lloyd S. *Saale.*
Through W. & A. Fletcher Co., Hoboken, N. J.
Forgings for Norwich Line Str. *City of Lowell.*
" " C. R. R. of N. J. Str. *Monmouth.*
" " M. C. D. Borden's Steam Yacht *Sovereign.*
" " Nantasket Beach Steamboat Company's Str. *Hingham.*
C. D. Mosher, New York City.
Forgings for Yachts *Ellide* and *Viper.*
A. Olsen, Brooklyn, N. Y.
Forgings for Norwegian Tramp Steamer S. *Bergen.*
Pacific Mail Steamship Co., San Francisco, Cal.
Forgings for S. S. *Colon.*
" " S. *San Blas.*
Macheca Brothers, New Orleans, La.
Forgings for S. *Stillwater.*
Old Colony Steamboat Co.
Forgings for Steamers *Priscilla, Pilgrim, Plymouth* and *Puritan.*
J. Rourke & Son, Savannah, Ga.
Forgings for S. *Bellevue.*
Through Union Iron Works, San Francisco, Cal.
Forgings for—
Pacific Coast S.S. Co., S. *Queen.*
Wilder S.S. Co., S. *Helena.*
Pacific Mail S.S. Co., S. *Newport.*
Lake Tahoe Steamer.
Oceanic S.S. Co., S. *Australia.*
Starin Ship Yard and Iron Works, New York City.
Forgings for Str. *Sam Sloan.*
International Navigation Co., Philadelphia, Pa.
Forgings for S.S. *New York* and *Paris.*
Through John N. Robins Co., New York, N. Y.
Forgings for H. B. Moore, Yacht *Marietta.*
Netherland Steam Nav. Company's S. *Amsterdam.*



MACHINE SHOP NO. 2. FOR GENERAL WORK ON GUN, MARINE SHAFTING AND MISCELLANEOUS FORGINGS AND FOR FINISHING GUNS.
DIMENSIONS, 1246 FEET X 117 FEET.

Elbridge J. Gerry's Yacht *Electra.* Fabre Line, S. *Alesia.*

Forgings for Norwegian Tramp Steamers—*Alfred Dumois*, *Oscar II.* and *Kitty.*

Compania Trans-Atlantica Espaniola S. *Mexico.*

Through Harlan & Hollingsworth Co., Wilmington, Del., for Joseph Wharton & Co., Philadelphia, Pa.

Forgings for Steamer *Active.*

Charles R. Flint, New York, N. Y.

Forgings for Yacht *Nada.*

Through F. W. Wheeler & Co., West Bay City, Mich.

Forgings for Rockefeller vessels.

Through Detroit Dry Dock and Engine Co., Detroit, Mich.

Forgings for Rockefeller vessels.

Through Shook, Anderson & Co., Pittsburg, Pa. for Joseph Walton & Co.

Shaft for Stern Wheel Steamer *Valiant.*

Through Cincinnati Marine Ways, Cincinnati, O.

Shaft for Pittsburg and Cincinnati Packet Company's Stern Wheel Steamer *Queen City.*

NICKEL STEEL PROPELLER SHAFT FOR THE U. S. CRUISER "BROOKLYN." HOLLOW FORGED. OUTSIDE DIAMETER, 17⅛ INCHES. INSIDE DIAMETER, 11 INCHES. LENGTH, 38 FEET 11⅜ INCHES. WEIGHT, 19,112 POUNDS.

These orders cover a range of territory extending along the Atlantic and Pacific Coasts, the Great Lakes and Western rivers, and including various grades of steel forgings, from the highest type of fluid compressed, oil-tempered nickel steel for the Government and high grade private yachts to ordinary high carbon steel for merchant marine engines.

Besides marine engine forgings, The Bethlehem Iron Company has supplied miscellaneous steel forgings of all grades and shapes and sizes for machinery and engines to representative machinery and engine builders all over this country and to foreign countries, and now stands ready to fill orders for steel forgings of any grade and description to purchasers, no matter where they may be located, or what their requirements may be.

The Bethlehem Iron Company stands ready to fill orders for steel forgings of any grade and description. Correspondence solicited.

A PANEL ON THE QUARTER DECK OF THE FALL RIVER LINE STEAMER "PRISCILLA."

LUXURIOUS STEAMBOAT INTERIORS.

TO a few of the many thousands of passengers on steamers the construction of the hull and the details of the machinery are particularly interesting, and these few are usually found making diligent inquiries and observations regarding the essentials of power and safety.

To the many, however, these are found to be of no great importance, or at least of so little importance that no interest in them is manifested and their eyes and thoughts are caught only by that which pertains for the time being to their physical comfort—the foyers, saloons, chambers and the decorations thereof.

On the Fall River Line steamers, referred to in another article in this magazine, all of these objects have received as much attention as those of power and safety, and no better examples of beauty can be found.

In order that each steamer built by the line should be finer and more attractive than not only its predecessor, but every other steamer afloat, the company selected Mr. William Rowland, of New York City, to prepare and erect the joiner work, which means the entire superstructure above the main deck, as well as the various cabins, kitchens and pantries that are to be found below the main deck.

Mr. Rowland has had long experience and exceptional ability in this line, having fitted up a greater number of steamships and steamboats than probably

any one else anywhere, and by his efforts has succeeded in giving on the Fall River Line steamers unsurpassed examples of taste, style and excellence.

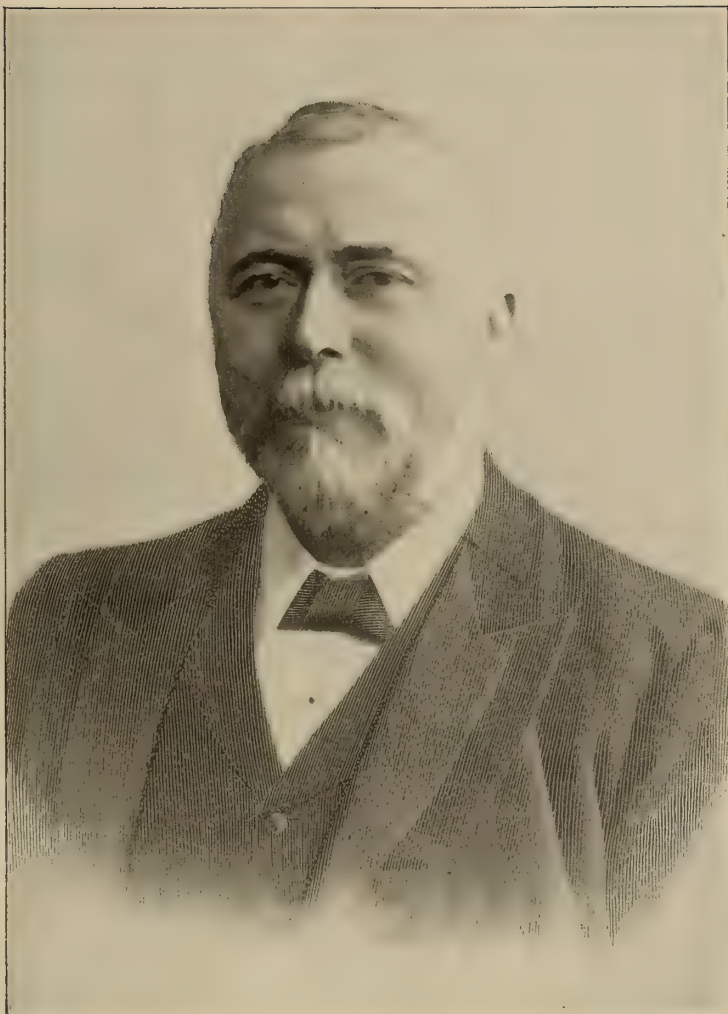
In addition to the magnificent fleet of sound and river steamers, Mr. Rowland has also fitted up, almost without exception, every ocean-going steamship engaged in our coastwise trade, and, as this magazine is being published, he is

WILLIAM ROWLAND.

just putting the finishing touches to the *Princess Anne*, the fine new steamer built during this past year by John Roach & Sons for the Old Dominion Steamship Company. Mr. Rowland personally supervises every detail of his vast business, which accounts in no small measure for his great success. In addition to his other large commercial interests he is a director of the Cuba Mail Steamship Company (Ward Line), the Old Dominion Steamship Company, the Farmers' Loan and Trust Company and the Eleventh Ward National Bank of New York.

MARINE NUMBER OF CASSIER'S MAGAZINE.

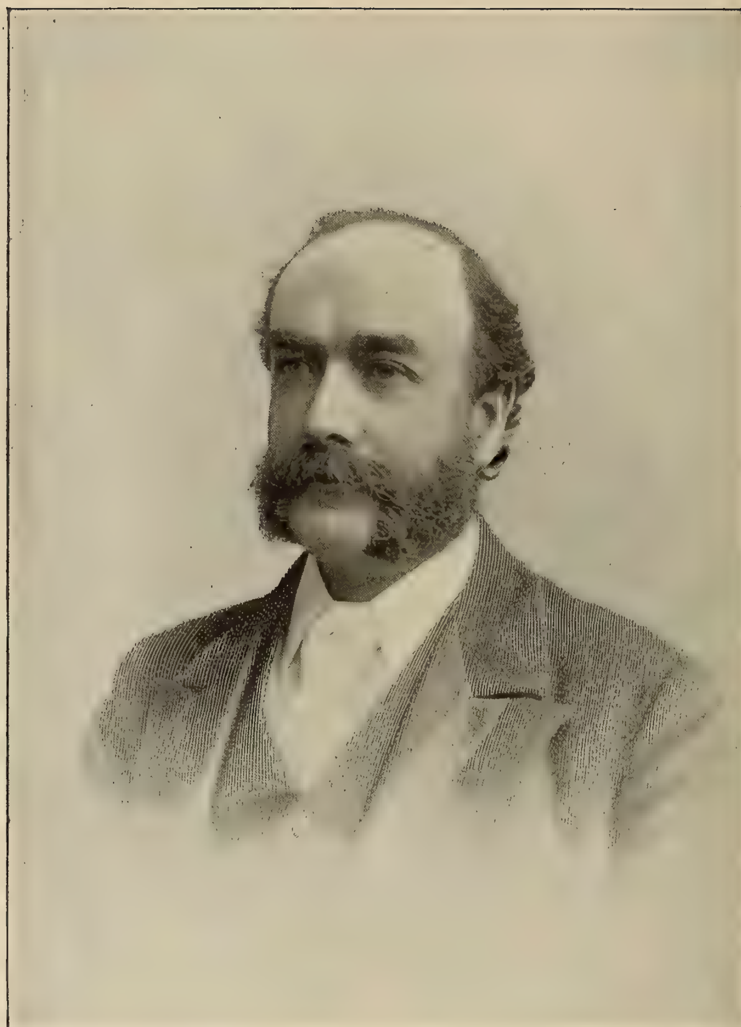
CONTENTS.



PHOTOGRAPH BY BYRNE & CO., RICHMOND.

W. H. White

SPECIALITIES OF WARSHIP DESIGN, with twenty-five illustrations, by Sir William H. White, K.C. B., LL. D., F. R. S., Assistant Controller and Director of Naval Construction of the British Navy.

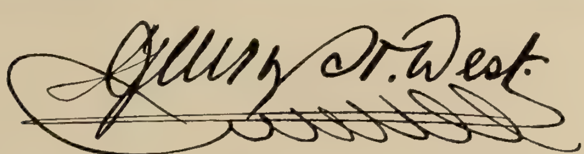


PHOTOGRAPH BY WAYLAND BLACKHEATH.

A. F. Yarrow

FAST TORPEDO BOATS, with thirty-five illustrations, by A. F. Yarrow, M. Inst. C. E. famous as a builder of fast torpedo boats and shallow-draught river steamers.

COPYRIGHTED PHOTOGRAPH BY BROWN, BARNES & BELL, LONDON.



THE PROBLEM OF STEAMSHIP DESIGN, with fourteen illustrations, by Henry H. West, M. Inst. C. E., the eminent British naval architect.

PHOTOGRAPH BY MC LENNAN, GREENOCK.

R Caird

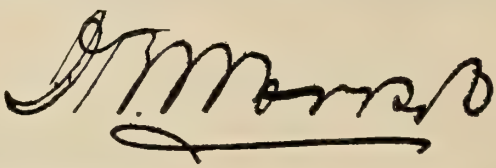
THE LAUNCHING OF A SHIP, with eleven illustrations, by Robert Caird, F. R. S. E., of the famous Caird shipbuilding firm at Greenock.

PHOTOGRAPH BY MAULL & FOX, LONDON.

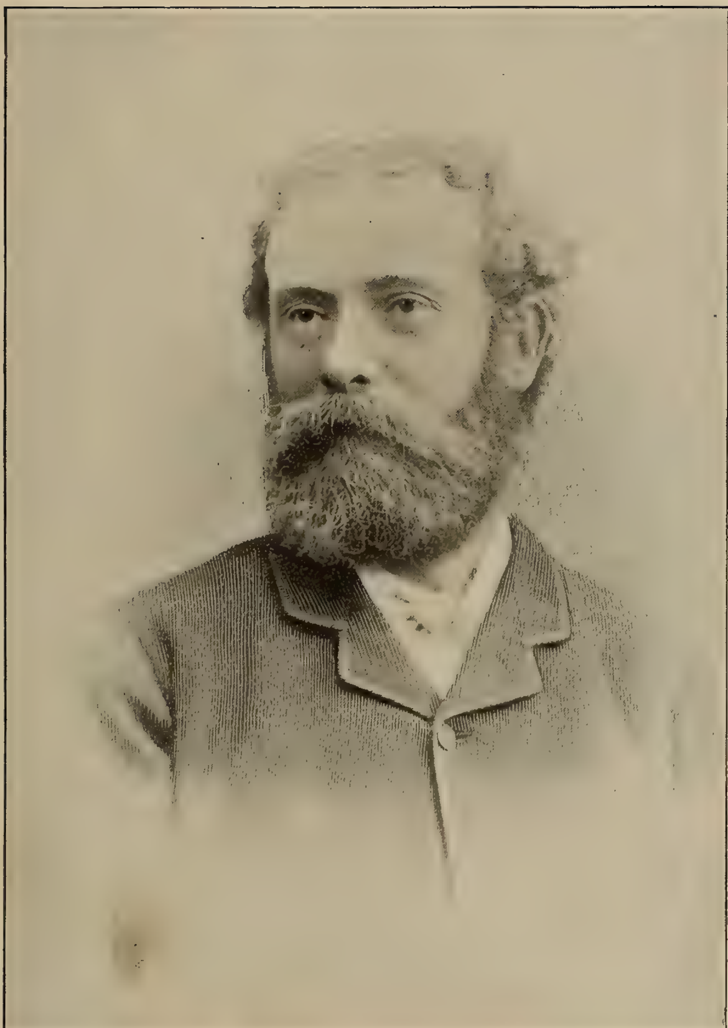
F. P. Purvis

HYDRAULIC PRINCIPLES AFFECTING A FLOATING SHIP, with fourteen illustrations, by F. P. Purvis, Managing Shipbuilding Partner of Messrs. Blackwood & Gordon, Shipbuilders, Port Glasgow.

PHOTOGRAPH BY JOHN HAWKE, PLYMOUTH, ENG.



*MARINE BOILER FURNACES, with twelve illustrations, by D. B. Morison, M. Inst. M. E., inventor of the Morison Suspension furnace.



COPYRIGHTED PHOTOGRAPH BY BARRAUD, LONDON.

John I. Thornycroft

STEAMERS FOR SHALLOW RIVERS, with thirty-one illustrations, by John I. Thornycroft, F. R. S., the famous specialist in this type of craft.

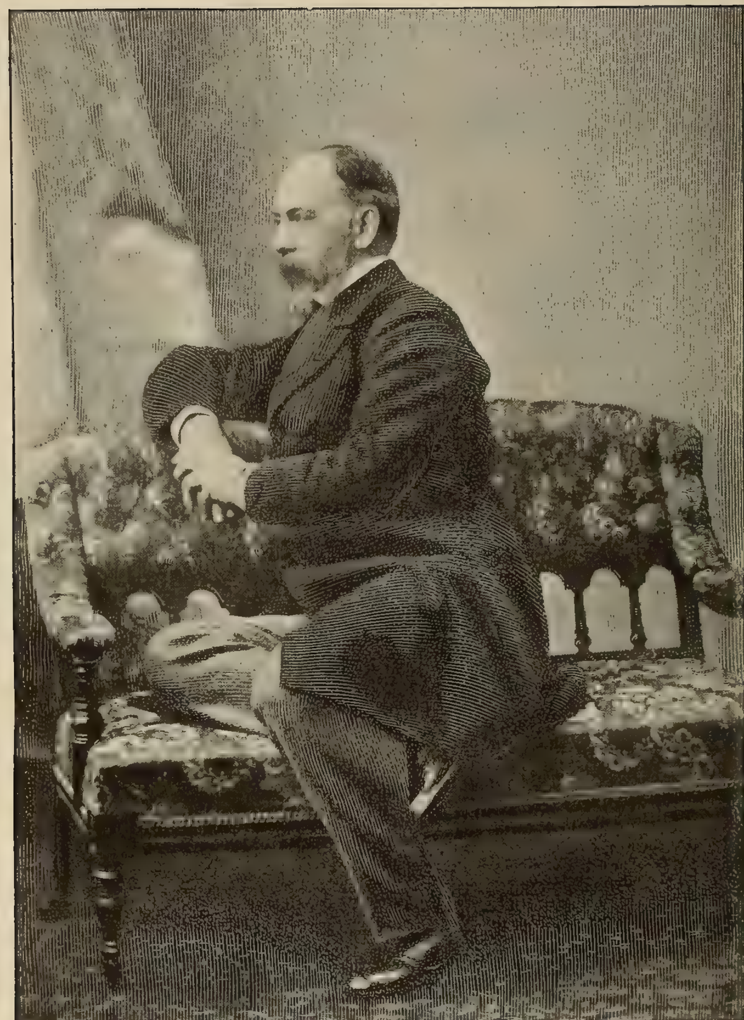
PHOTOGRAPH BY SEBASTIANUTTI & BENQUE, TRIESTE.

A. Denny

THE DESIGN AND BUILDING OF A STEAMSHIP, with fourteen illustrations, by Archibald Denny, M. Inst. N. A., head of the technical staff of the well-known shipbuilders, Messrs. William Denny & Bros.

W. M. McFarland

WATER TUBE BOILERS FOR WAR VESSELS, with sixteen illustrations, by Walter M. McFarland, Passed Assistant Engineer of the United States Navy.

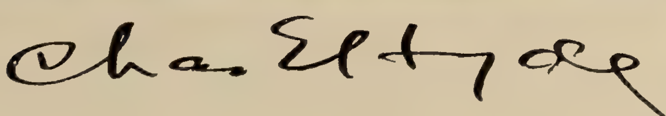


PHOTOGRAPH BY DICKINSON, LONDON.

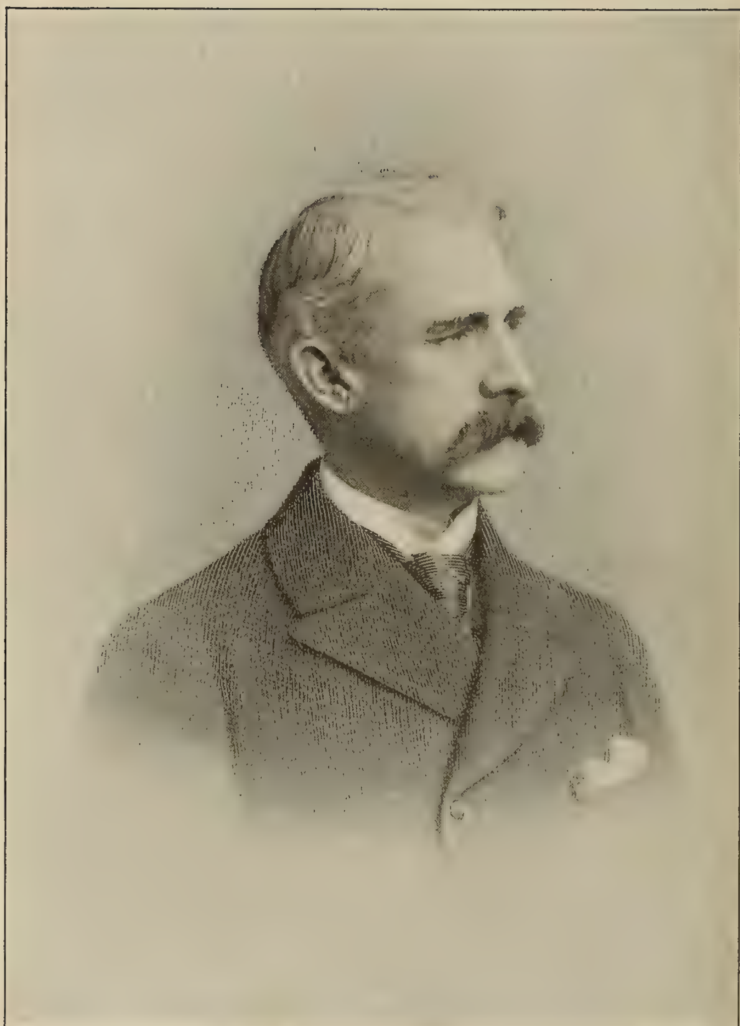
Charles W. Dilke.

THE NAVAL WEAKNESS OF GREAT BRITAIN, with ten illustrations, by Sir Charles W. Dilke, Bart., M. P.

PHOTOGRAPH BY SARONY, NEW YORK.



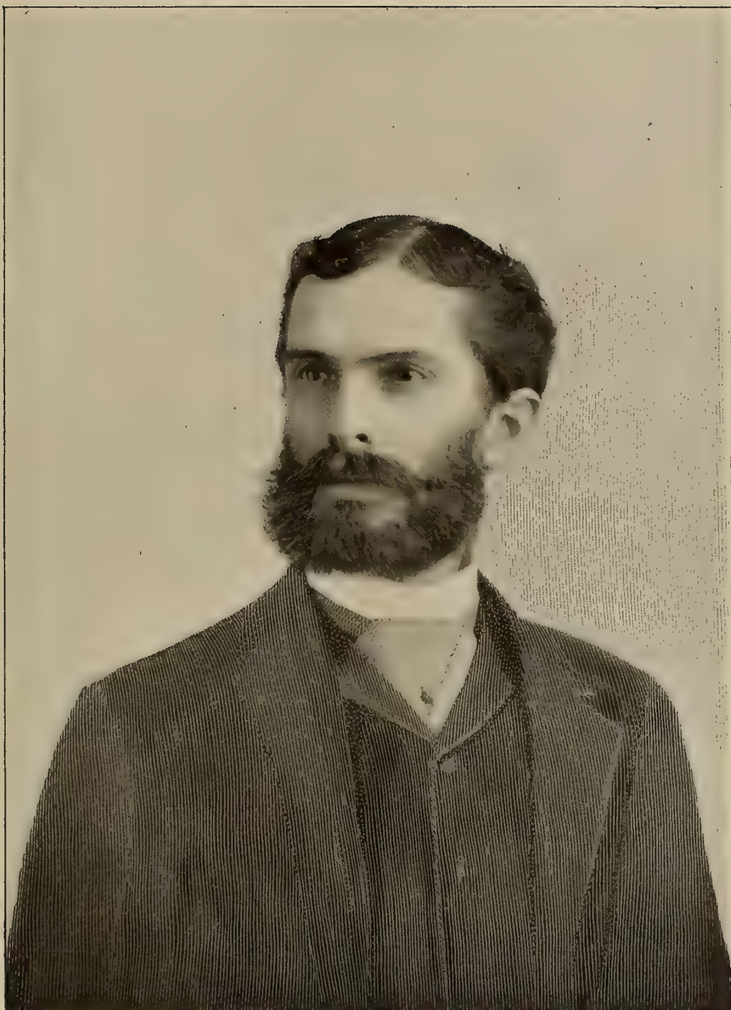
THE MODERN MARINE ENGINE, with thirty-six illustrations, by Charles E. Hyde, M. Am. Soc. M. E., Engineer of the Bath Iron Works.



PHOTOGRAPH BY LANGHORNE. PLAINFIELD, N. J.

Leander N. Lovell

AMERICAN SOUND AND RIVER STEAMBOATS, with twenty-two illustrations, by Leander N. Lovell, Senior Officer of the Old Colony Steamboat Co.



PHOTOGRAPH BY PARKINSON, NEW YORK.

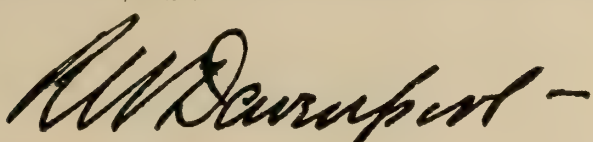
F. Meriam Wheeler

THE AUXILIARY MACHINERY OF AN AMERICAN WAR SHIP, with seventeen illustrations, by F. Meriam Wheeler, Constructing Engineer for the Geo. F. Blake Mfg. Co.

PHOTOGRAPH BY JOHN H. RYDER, CLEVELAND, OHIO.

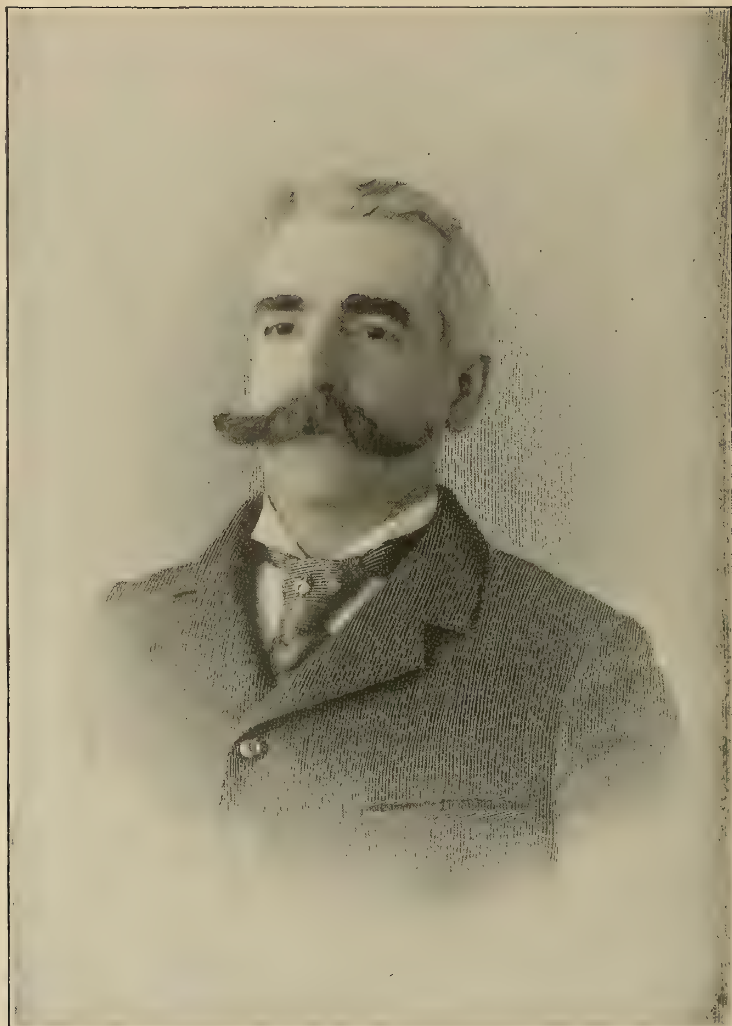
Shipbuilding on the Great American Lakes, with thirteen illustrations, by J. R. Oldham, Naval Architect and Marine Appraiser on the Great Lakes.

PHOTOGRAPH BY L. ALMAN & CO., NEW YORK.



STEEL FOR MARINE ENGINE FORGINGS AND SHAFTING, with seventeen illustrations, by Russel W. Davenport, Vice-President of the Bethlehem Iron Co.

4-2

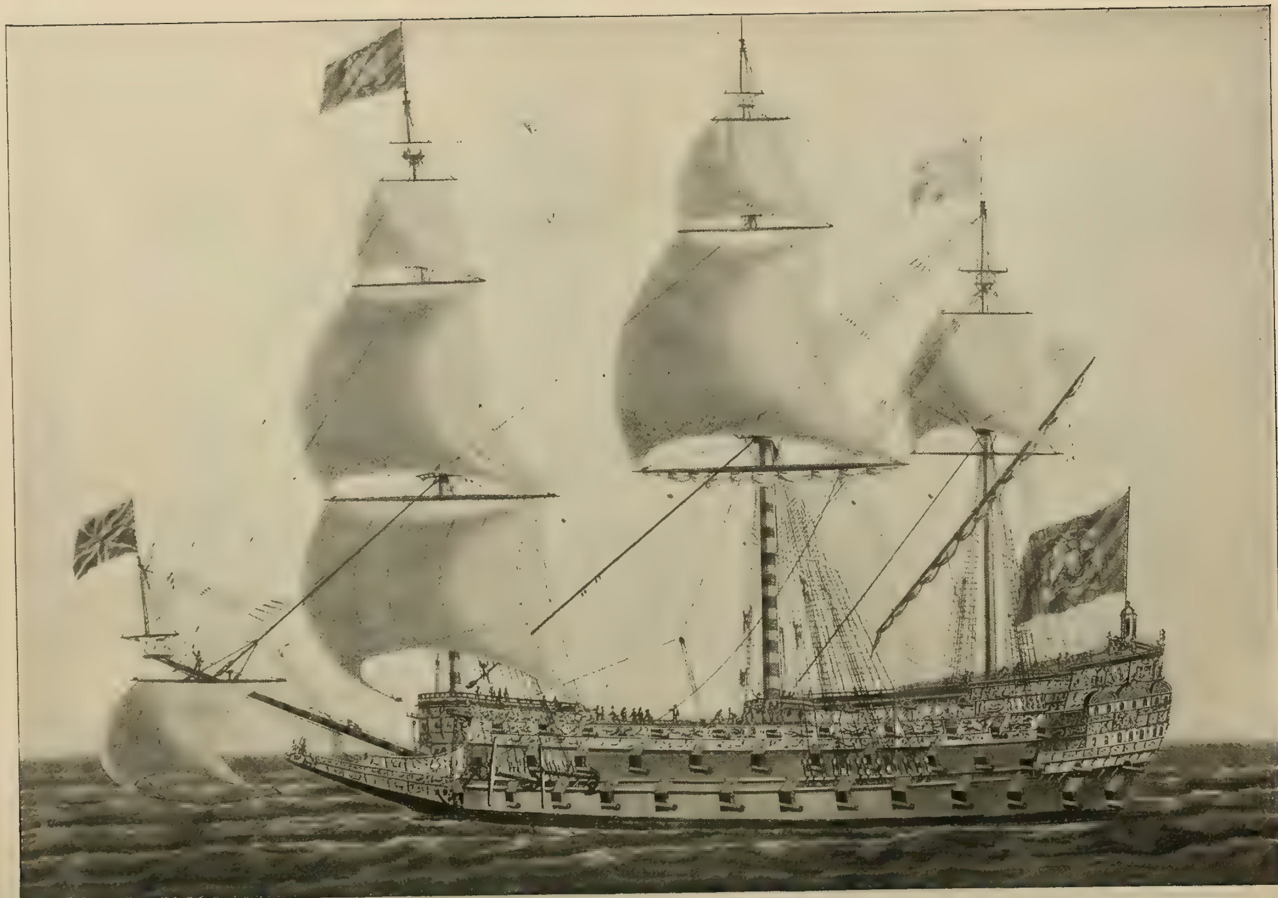


S. Howard Smith

THE COALING OF STEAMSHIPS, with twelve illustrations, by S. Howard Smith, Vice-President of the Link Belt Engineering Co.

John P. Holland.

SUBMARINE NAVIGATION, with seventeen illustrations, by John P. Holland, Designer of the Holland submarine boat.



THE "SOVEREIGN OF THE SEAS." BUILT IN 1637.

From an Original Picture by Vandevelde.

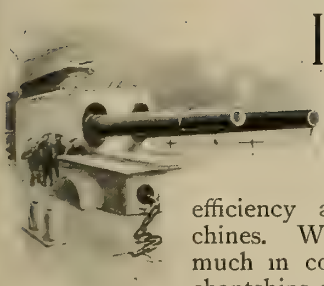
Marine Number.

CASSIER'S MAGAZINE.

VOL. XII. AUGUST, 1897. No. 4.

SPECIALITIES OF WARSHIP DESIGN.

By Sir William H. White, K. C. B., L.L. D., F. R. S.



IN all ages warship designs have been specialised in order to fulfill the primary requirements of efficiency as fighting machines. Warships may have much in common with merchantships constructed at the same period. Materials and methods of construction, many portions of the equipment and modes of propulsion may be similar. But there must be essential differences since warships exist for use in battle, and merchant ships for purposes of trade, the safe conveyance of passengers and cargoes, and the realisation of profits on the capital invested in them.

At different periods the degree of divergence between the two classes has varied greatly. It has never disappeared, and under modern conditions has attained a maximum. The main purpose of this paper is to illustrate and explain the marked differences at present existing between warships and merchant ships. Before doing so a brief glance may be bestowed on the past history of the specialisation of warships.

So long as oars constituted the chief means of propulsion, war-galleys excelled in size, strength, speed and complement. In certain features their structures were governed by consideration of fighting efficiency. Their bows were suitably formed and strengthened for ramming. Their upper works, especially towards the extremities, differed entirely from those of merchant ships, being designed so as to utilise existing weapons of offence, or to give their fighting force positions of vantage in the hand-to-hand conflicts then in vogue. The differences between warships and merchant ships were then obvious and considerable.

As ships increased in size, and oversea voyages were undertaken, sails necessarily came into use as supplements to, or substitutes for, oars. The change of practice was more rapid, no doubt, in the fleets of Western Europe than in those of the Mediterranean, but everywhere progress was slow and improvement very gradual. One effect of the use of sails, and the consequent economy in propulsion, was to make merchant ships approximate more closely to warships in size and power.

The "King's Ships" of England in the thirteenth century, built primarily for war service, were lent to merchants and employed for commercial purposes during peace. Mercantile auxiliaries furnished by the Cinque Ports or other seaports, took their places alongside the King's ships during war. But even then King's ships appear to have pos-

COPYRIGHTED BY MESSRS. SYMONDS & CO., PORTSMOUTH.

THE BRITISH BATTLE SHIP "ROYAL SOVEREIGN." TWIN SCREWS. DISPLACEMENT, 14,260 TONS. I. H. P., 13,312. SPEED, 18 KNOTS.

sessed distinctive features,—forecastles, poops and fighting tops—probably survivals from war-galley construction, not usually appearing in merchant ships. To turn the latter into auxiliaries to the war fleet, corresponding features were often extemporised, armaments were added, and the ordinary crews were supplemented by fighting complements of soldiers. Thus transformed, merchant ships were practically equal to King's ships, and in size the largest of them were not inferior. Canynge, of Bristol, and other merchants of the fifteenth century appear to have owned some of the largest ships afloat.

The use of guns on ship-board initiated a change in these conditions, of which the far-reaching effects were not realised until more than a century had passed. Descharges, a shipbuilder of Brest, is said to have first constructed port holes in the sides of warships about the year 1500. He and his successors were thus able to superpose tier on tier of guns, in the broadside armaments of warships. In fact, up to 1860 the same fundamental ideas prevailed in the disposition of armaments.

Increase in power was represented by increase in the number of guns carried, rather than in any great advance in the size or force of individual guns. With wood hulled sailing ships moderate lengths were necessarily favoured, as they secured hardiness and made more easy the provision of structural strength. As a result, there appeared first the "two-decker," or battle ship with two tiers of guns; then the "three-decker," and finally a few examples of the "four-decker." The last mentioned type was not adopted for the Royal Navy, although designs were prepared. In the Spanish Navy there were four-deckers, and the *Santissima Trinidad*, which fought at Trafalgar, was of this class.

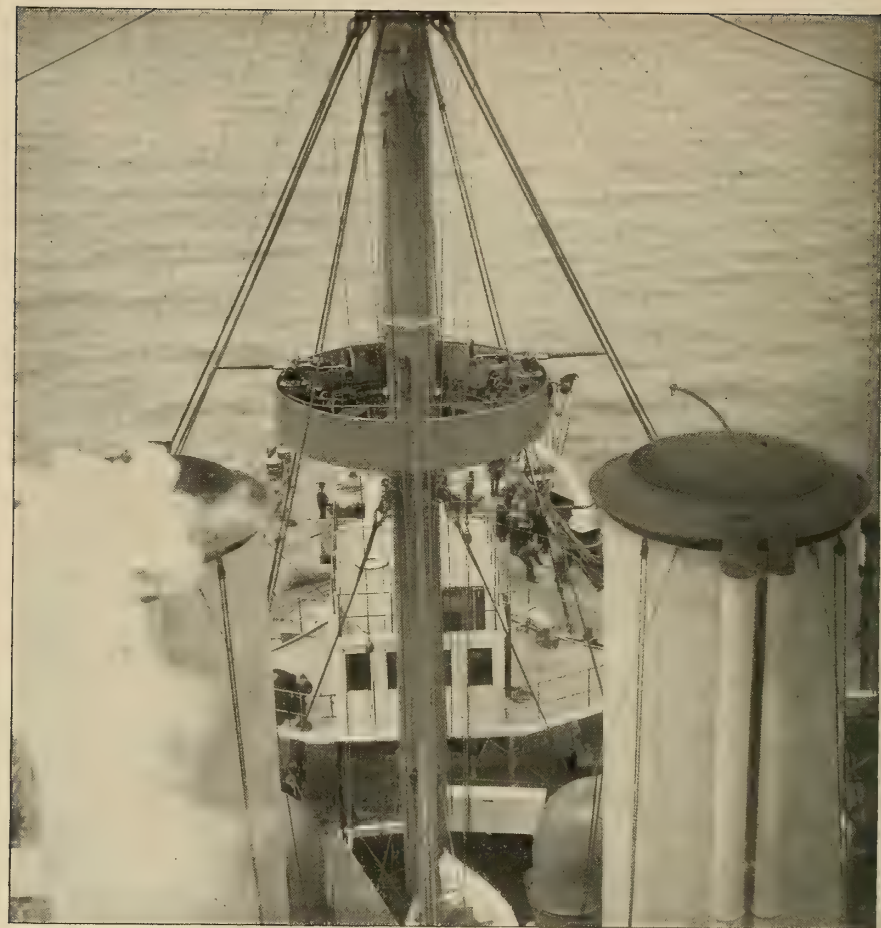
For six centuries, it may be said, sails remained the principal means of propulsion and wood the chief material of construction. Smooth-bore guns, firing spherical shot, mounted on rude wooden carriages on the broadside, and worked by manual power, formed the principal armaments for 500 years. Until the seventeenth century, mercantile auxiliaries were chiefly depended upon in naval warfare, the number of regularly built warships being comparatively small.

The English Channel fleet which defeated the Spanish Armada, had only 34 Queen's ships out of 197 vessels of all sorts and sizes. An analysis of the lists shows, however, that the largest Queen's ships greatly exceeded in tonnage and armament the largest mercantile auxiliaries present, including those which the great "adventurers" commanded, and which had been really constructed or equipped for use as armed vessels in distant seas, rather than for peaceful mercantile employment.

This glimpse into the past shows that by the end of the sixteenth century the warship had diverged greatly from the merchant ship, and that the development of gun power had produced essential differences of type and greater dimensions. Progress continued on the same lines, and by very slow degrees up to the time when the iron-clad reconstruction began. The application of steam power to warship propulsion, of course, involved an entirely new departure. Still, this was in the form of an addition to what had been attained during centuries of adherence to one system. Sail power was retained, wood was still used for the hulls, and line-of-battle ships were still armed with two or three tiers of smooth-bore muzzle-loading guns, distributed along their broadsides, with simple mountings worked by manual power. Charnock, writing at the commencement of this century, said of the *Prince Royal*:—

"This vessel (built in 1610) may be considered the parent of the identical class of shipping which, excepting the removal of such defects or trivial absurdities as long use and experience has pointed out, continues in practice even to the present moment."

Very much the same might have been said half a century later, as sailing line-of-battle ships were even at that date supreme in the Royal Navy. The following table speaks for itself. It illustrates not merely the slow rate of change



COPYRIGHTED BY MESSRS. WEST & SON, SOUTHSEA.

FIGHTING TOP OF THE "ROYAL SOVEREIGN."

in warship construction, but indicates how far warships had departed from merchant ships in size and type. There was nothing in the mercantile marine, before the era of steam navigation, comparable in size or power to line-of-battle ships with their towering sides and numerous armaments. Even the frigates in war fleets, with single gun decks, compared favourably in size with the largest merchant ships existing at the end of the great French war. The smaller classes of corvettes, brigs and sloops were more than a match in fighting power for most merchant ships.

In certain special services, such as that of the East India Company, vessels were used which combined good fighting qualities with cargo carrying capacity. Privateers of special types were also employed. Ordinary merchantmen were no longer of value as auxiliaries to warships. Under the influence of a vicious tonnage law they were bad sea-boats and "dull sailers," and, besides, were unsuitable for armament. Fighting efficiency had so specialised all warship design that naval warfare was practically restricted to vessels built for that purpose.

The problems to be faced in building the grand and beautiful structures of these obsolete types of battle ships exceeded greatly in difficulty anything that then had to be solved in connection with merchant ships. Those of us who

are personally acquainted with the work done prior to 1860, as well as with present conditions, agree in recording our appreciation of the technical skill and courage displayed by our predecessors in building such vessels of wood. Ruskin stated but the simple truth when he said that into such ships " man has put as much of his human patience, common sense forethought, experimental philosophy, self-control, habits of order and obedience, thoroughly wrought hand work, defiance of brute elements, careless courage, careful patriotism, and calm expectation of the judgment of God, as can well be put into a space 300 feet long by 80 feet broad."

Particulars of 1st Rates (Three-Deckers).

	Sovereign of the Seas.	*Britannia.*	*Victoria.*
Date	1637	1837	1860
Length	170 feet.	205 feet.	260 feet
Breadth	48	54½	60
Burthen (in tons)	1,680	2,600	4,100
Displacement (in tons)	3,000	4,800	7,000
Armament:—			
Total No. of guns	102	120	121
	20, 42 to 60 prs.	32, 32 prs.	1, 68 prs.
	8, 30 prs.	34, 24 prs.	62, 56 prs.
	32, 18 prs.	34, 18 prs.	58, 32 prs.
	42, 9 prs.	8, 12 prs.	
		12 carronades.	
Officers and men	600	1,000	1,150
Area of sail; sq. ft.	not known.	26,650	31,000
Indicated horse-power	sails only.	sails only.	4,200
Cost, excluding armaments	£41,000	£117,000	£217,000

Note.—The particulars of the *Sovereign of the Seas* must be considered as somewhat doubtful, especially those for length and tonnage.

Forty years have elapsed since the introduction of armour for seagoing ships. Paixhans, who did so much to develop horizontal shell fire, had recommended the plan thirty years before. It required the personal influence of Napoleon III., backed by the technical skill of his naval constructor, Dupuy de Lome, to initiate the change. In doing so they could not have possibly anticipated that into these forty years would have been crowded far greater advances in the design, armament, and equipment of warships than had been made in centuries preceding.

Using the term in its broadest sense, it may be said that " armour protection " has produced a greater gap than previously existed between the governing conditions of the design of warships and merchant ships. Mercantile auxiliaries are still of value for many services in naval warfare; but in actual fighting, the largest and swiftest merchant steamers are no match for much smaller vessels whose designs have been dominated by the development of offensive and defensive powers. This is true even when protection has been extemporised for machinery and steam pipes, and the best possible arrangements have been made for armaments.

It was an entirely new departure to clothe over with heavy loads of iron plating the whole, or portions, of the sides of ships, from a few feet below water to a considerable height above. New structural arrangements had to be devised; new problems in stability to be solved; wood had to give place to iron and steel as the principal material of construction. The towering, unarmoured three-decker, with her 121 guns, was no match for the frigate-built *Warrior* with her 38 guns, all of the most powerful types then available and nearly all behind armour which was practically impenetrable. Two and three-deckers in process of construction were " cut down " to frigates and " converted " into iron clads. The object lesson afforded by the destruction of the Turkish fleet at Sinope, by shell fire from the Russian fleet, could not be ignored.

Then began the unceasing struggle between guns and armour. On the one side, wonderful developments in artillery, such as were previously unimagined, and unnecessary; in explosives and projectiles; in methods of mounting and working guns; on the other side, improvements in the manufacture of armour, variations in its disposition, and manifold changes in details, intended to give greater defense.

With steam propulsion and iron hulls came the revival of the ancient mode of attack by ramming, bringing with it the need for exceptional manœuvering power, as well as for special structural arrangements of ram bows, and of internal subdivision, designed to limit injuries done by ramming. The invention of automobile torpedoes added a terrible weapon to the means of under water attack, necessitating special devices for

COPYRIGHTED BY MESSRS. W. GREGORY & CO., LONDON.

THE ADMIRAL'S STERN-WALK ON BOARD H. M. S. "MAGNIFICENT." TWIN SCREW BATTLE SHIP. INDICATED H. P., 10,000. DISPLACEMENT, 14,900 TONS.

its installation in and ejection from ships, and plans for the defense of ships against torpedoes. All these factors in the designs of warships have no counterparts in those of merchant ships, and explain the wide divergence which has arisen between the two classes.

In a period marked by rapid changes in war material, as well as by an experience in naval warfare happily very limited, it was inevitable, not merely that correspondingly rapid changes of type should take place, but that there should be considerable differences of opinion as to the types most suitable for adoption at a particular time. There is no longer a definite classification of warships such as formerly prevailed. Every one knew what a "first rate" battle ship meant fifty years ago. Now, opinions differ widely, and with good reason, as to the relative fighting values of different types ranking as "battle ships." Under existing conditions it is possible to develop greatly power of one kind at the expense of another; and there is no standard of reference for that desideratum to which all profess to as-

pire,—a "well balanced design," combining most perfectly powers of offense and defense.

It is not proposed in this paper to discuss the relative values of existing types, the comparative merits of different systems of protection and armament, or to describe in detail the task of the warship designer. Apart from restriction of space, the writer, as one who has been engaged for thirty years in designing warships, has no desire to describe his own work or to criticise the work of others. What is desired is to bring into relief some of the many limitations and difficulties incidental to warship construction. A convenient introduction to this may be found in the accompanying diagrams, representing the main features of armour and armament in different types of battle ships belonging to various navies.

Fig. 1 represents a "completely protected" ship, such as the French *La Gloire* of 1857 or English *Minotaur* of 1861, armoured from a few feet below water to the upper deck, throughout the length. Her armament consisted of a considerable number of guns, of the heaviest type then available, mounted on the main deck, and fought at broadside ports. When built, these early iron clads were proof against the shot as well as shell of the heaviest guns afloat, and their own protected guns practically commanded the horizon.

More powerful guns were soon devised, greater thicknesses of armour had to be used, and the armoured area was reduced. The "central battery and belt" system (Fig. 2) was then adopted. A smaller number of heavier guns was mounted in the central battery, and increased horizontal command was obtained by having recessed ports at the angles, as well as broadside ports. In a few instances the central battery was double-storied. In many cases outlying armoured batteries at bow and stern were associated with central batteries to increase the range of horizontal command from protected guns. Guns up to 18 and 25 tons in weight were mounted in the central batteries of ships of this type, which held its ground from 1862 to 1878 in most navies.

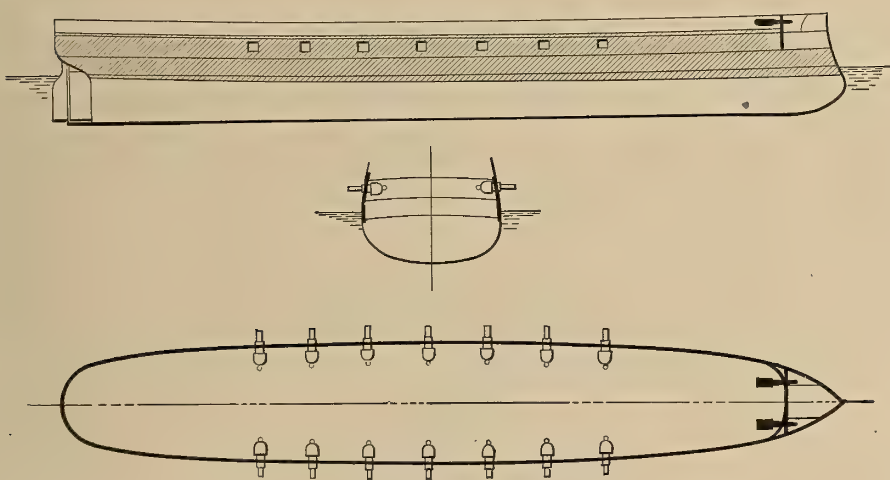


FIG. 1. "MINOTAUR."

The turret system of mounting heavy guns had been in use almost from the outset of the iron clad reconstruction. Its prominent advocates were Ericsson in America, and Cowper Coles in England. Many ships had been built, mostly of small size, and the great advantages of the system had been demonstrated. The successes achieved by the

Monitors in the American Civil War, and the visit paid to Europe by the *Miantonomah* in 1866, caused greater attention to be given to the system as applied to seagoing ships.

In 1869 a bold step was taken by the ing 35 tons, mounted in two turrets with their axes at a moderate height above water. Complete command of the horizon was given to these guns, the upper deck forming a *glacis* over which they fired. The hull proper, like

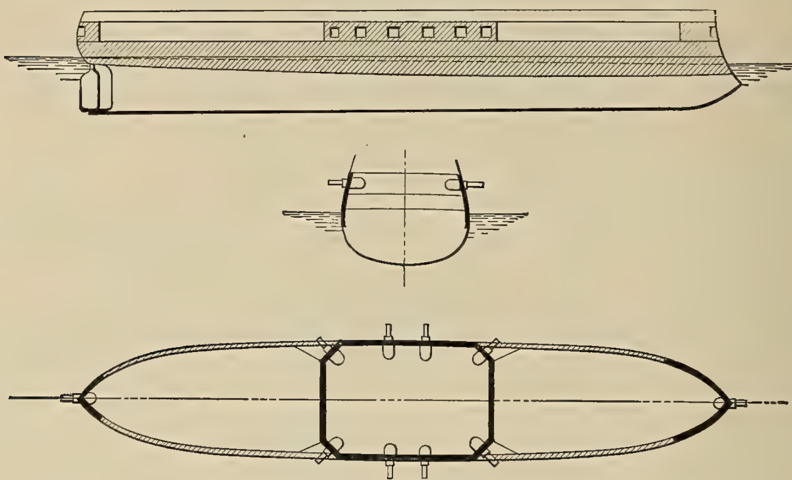


FIG. 2. "HERCULES."

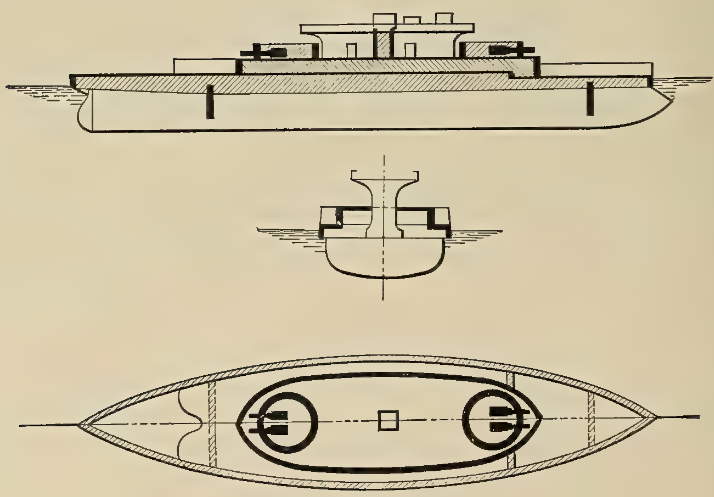


FIG. 3 "DEVASTATION."

English Admiralty at the suggestion of Sir Edward Reed, by the design of the *Devastation* class (Fig. 3). There were many novel features in this ship, and her sister the *Thunderer*. Her armament consisted of four guns each weigh-

that of Ericsson's *Monitor*, was armoured throughout the length at the water line, and had only about three feet of freeboard.

Upon the protected deck closing in the armoured hull, stood an armoured

"breastwork," enclosing engine and funnel hatches, and protecting the bases of the turrets. Masts, rigging and sails were abandoned. Twin-screws and duplicated engines were depended upon for propulsion. The coal supply was large. In consequence of the moderate height of the guns above water, the height of the armoured target presented by the ship was small. Thick armour was carried on hull, breastwork and turrets. In fact, the design constituted one of the most striking examples seen, up to that date, of the domination over all other considerations of the development of offensive and defensive power.

Artificial ventilation and lighting were necessary almost everywhere. For smooth water service the type was excellent. As first proposed the margin of stability for sea service was not thought sufficient, and light "superstructures" were added outside the breastwork. Subsequent experience showed the type to be perfectly safe in all weathers, but the moderate height of guns prevented their free and efficient use in heavy seas. The absence of a secondary armament of lighter guns, also greatly impaired the fighting efficiency, when rival types began to be constructed in which that feature was developed.

Fig. 4 illustrates the much discussed "central citadel type" in which both armour and armament reached the maximum of concentration. The ends have no vertical armour, but are constructed with strong under water steel decks, the spaces above being minutely subdivided and, to some extent, packed with cork. The turrets are placed *en echelon* in order to enable all four guns to have unusually large horizontal command. Very thick armour is fitted on citadel and turrets. Here the difficulties of ventilation of hold spaces are very great, and the installation of machinery and boilers present unusual difficulties. A few light guns are mounted on the superstructures, but the great command of the heavy guns makes them of small value in action. The *Inflexible* is the largest vessel of this class and bore a distinguished part in the bombardment of Alexandria in 1882, where her four 80-ton guns proved most effective.

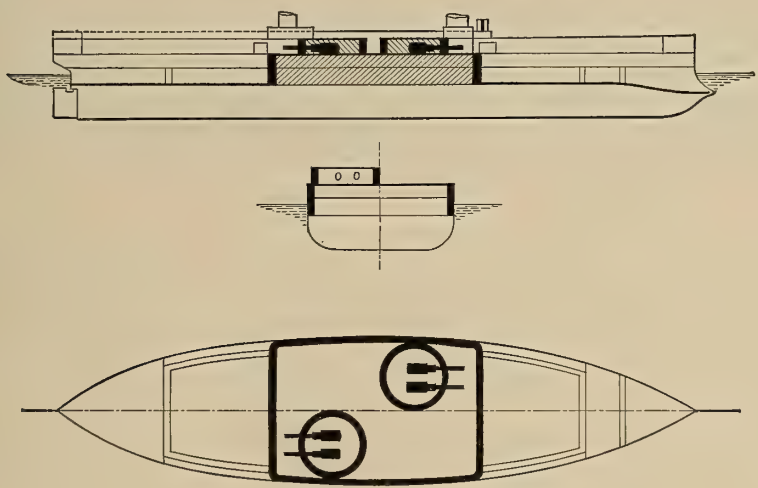


FIG. 4. "INFLEXIBLE."

Fig. 5 shows the arrangement adopted by French designers after the war with Germany, and in view of the large use by England, from 1869 to 1878, of turret ships having moderate freeboards, with a few heavy guns, placed at a relatively small height above water. The distinctive features are the mounting of four heavy guns in separate armoured

barbettes at a great height above water; the association with these guns of a number of lighter guns, unprotected, on the main deck; and the restriction of vertical armour on the hull to a narrow belt in the region of the water line.

Fig. 6 represents the *Italia* class of the Italian Navy, carrying four guns, each weighing 100 tons, on two turn tables, *en barbette*, within a single armoured enclosure placed at a great height above water. A numerous secondary armament is placed in an unprotected battery on the main deck. There is no vertical armour at the water line. A strong under water protective deck covers the hold space, and above it is a space minutely subdivided into compartments.

Fig. 7 represents the *Sinope* class of the Russian Navy, of which there are four examples in the Black Sea fleet. There are six 50-ton guns in the heavy armament, mounted in pairs on three turn tables in one armoured enclosure. The secondary armament is widely distributed and unprotected. A water line belt of armour extends throughout the length.

The development of secondary armaments has been accelerated during the last ten years by the extension of the quick-firing principle to guns of larger calibre. This development in no small measure resulted from the "shrinkage of armoured area" which had been in progress while guns were being increased in individual weight and power, and armour thickened. It has had an influence in two principal directions. First, there has been an extension of the armoured areas on the sides of recent battle ships; second, the necessity has been admitted for giving to the crews and guns of the secondary armaments of ships protection from an enemy's quick firers. These fundamental ideas have been carried into effect in various ways by different designers.

Fig. 8 shows the French *Charlemagne*. Her armament includes four 12-inch guns of about 50 tons weight, carried in two turrets, placed high above water; a number of 14 centimetre quick-firers, in a thinly armoured battery, situated between the turrets; and several other quick firers of various calibres with shield protection only, mounted on bridges or weather deck. The hull protection consists of a water line belt of thick armour, and a narrow strip of thin plating above it. This diagram affords a striking illustration of the manner in which the character

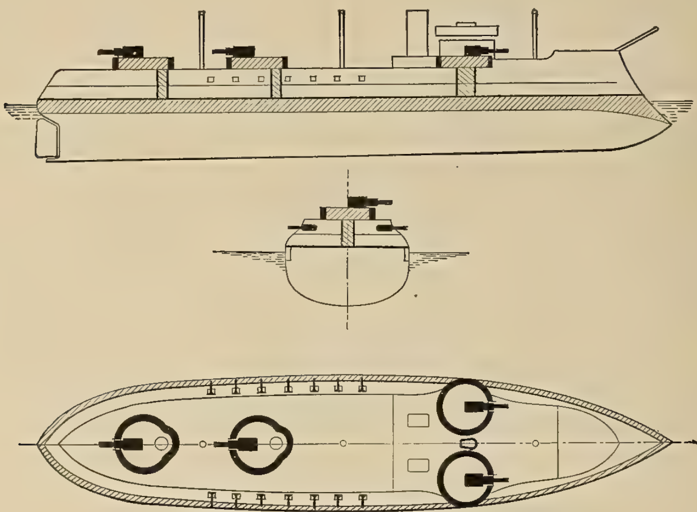


FIG. 5. "ADMIRAL DUPERRÉ."

INSIDE A TURRET ON BOARD THE U. S BATTLE SHIP "MASSACHUSETTS."

and disposition of the armament affects the designs of warships. The high freeboard and lofty superstructures grow out of the plan of gun armament.

Fig. 9 shows the latest German battle ship, *Kaiser Friedrich III.* There are four heavy guns in two turrets and a very large number of 15 centimetre quick firers, some in isolated batteries, or casemates, and some in revolving turrets. The hull protection consists of a water line belt of armour extending over about four-fifths the length, with an under water deck aft.

Fig. 10 shows the latest type of American battle ship; *Alabama* class. Her four heavy guns are in two turrets. Her quick firers are in an armoured battery, placed between the turrets, and in casemates above the battery. She has a water line belt of thick armour over about two-thirds the length, carried to the bow by thin armour and an under water deck aft. Above this thick belt there is a central citadel of thin armour, rising to the floor of the battery.

Fig. 11 shows the *Majestic* class, the most recently commissioned battle ship of the Royal Navy. The four heavy (12-inch) guns are mounted in pairs within fixed barbette towers, and have strong armoured shields revolving with them. Between the heavy guns, in isolated casemates are carried twelve 6-inch quick firers. The hull protection consists of an uniformly armoured citadel, the ends of which wrap round the barbettes, reaching to the height of the main deck. Outside the limits of the citadel the ends have no vertical armour, but there is a strong steel under water deck and minute subdivision of the space above it.

In this class the protective deck, instead of being worked horizontally and placed a few feet above water, as it is in ships with thick water line belts, is curved down at the sides to meet the lower edge of the citadel armour. It will be noted that the disposition of armament secures practical non-interference of gun with gun, great horizontal command, and that there is much less top hamper and superstructure than appears in some of the previous diagrams.

The foregoing illustrations indicate

how battle ship design has been and is dominated by the desire to make gun armaments as effective as possible, and to secure protection from the attack of an enemy's guns. Ram and torpedo have their influence also, but the gun is supreme. Now that some form of *protection* is universally admitted to be necessary on all except the smallest classes of war vessels, because of the developments of artillery, projectiles and explosives, it may be said of cruisers as well as battle ships, that the gun chiefly influences their designs. The degree in which that influence is felt depends, of course, upon the nature of the protection and its extent, and upon the character and disposition of the armament.

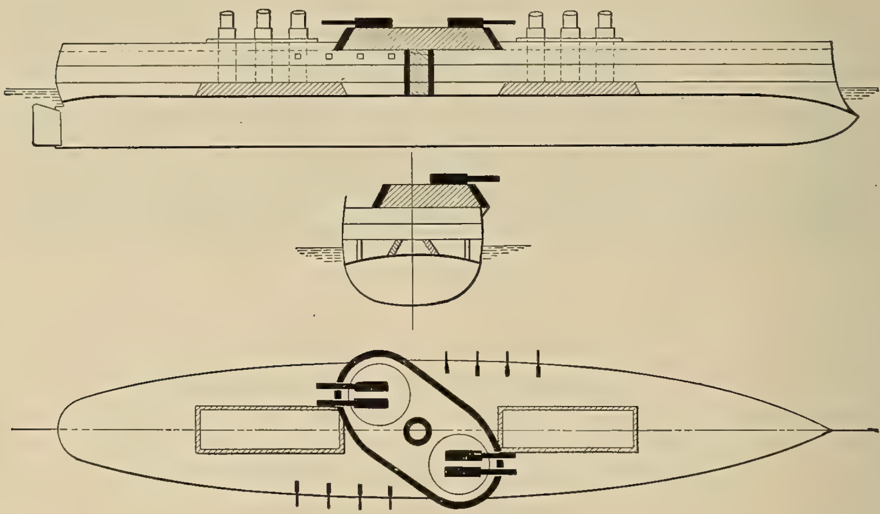


FIG. 6. "ITALIA."

But even in cruisers there are difficulties and limitations unknown in merchant ships. For example, the distribution of the hold spaces, situated under protective decks, is a matter not easily dealt with. Important sections of the propelling apparatus and the equipment must have protection. Upon the continued efficiency of these so-called 'vitals" of a warship her power as a fighting machine depends. Magazines and shell rooms, torpedo rooms, ammunition passages, coal bunkers, steering engines and gear, auxiliary machinery of all kinds—for compressing air, lighting by electricity, ventilation, working heavy guns, hoisting ammunition and other services—have to be provided for, in addition to the main propelling engines and boilers. Every available space has to be appropriated to, or fitted for, some special service. It has to be remembered that, in action, fore-and-aft communiciations under protection must be available, while ventilation and habitability must not be overlooked. Rival and to some extent conflicting claims have to be considered, and if the naval architect does not always give complete satisfaction to demands from the marine engineer, gunner, torpedoist, and naval officer, it is hardly to be wondered at. The drawings of a modern battle ship given in Fig. 12, illustrate the minuteness of the subdivision into separate watertight compartments, all of which are allocated to some special service.

The motto of a warship designer is: —" A place for everything, and everything in its place." He has no freedom outside engine and boiler rooms such as is found in merchant ships with their more or less spacious holds for cargoes, and ample openings in decks.

Marine engineers also have to carry out their work in warships without the comparative freedom enjoyed in merchant ships. Sometimes it is asserted that their difficulties are imposed by the naval architect without reason. This is not correct. The difficulties arise from the necessities of the case, and from no whim or fancy. An extreme instance will illustrate the point. In a central citadel iron clad, like the *Inflexible* (Fig. 4), all openings from machinery and boiler spaces to the outer air must come within the limits of the citadel. Consequently these spaces must underlie the citadel. But within that armoured enclosure must come the turret bases, the ammunition trunks, the

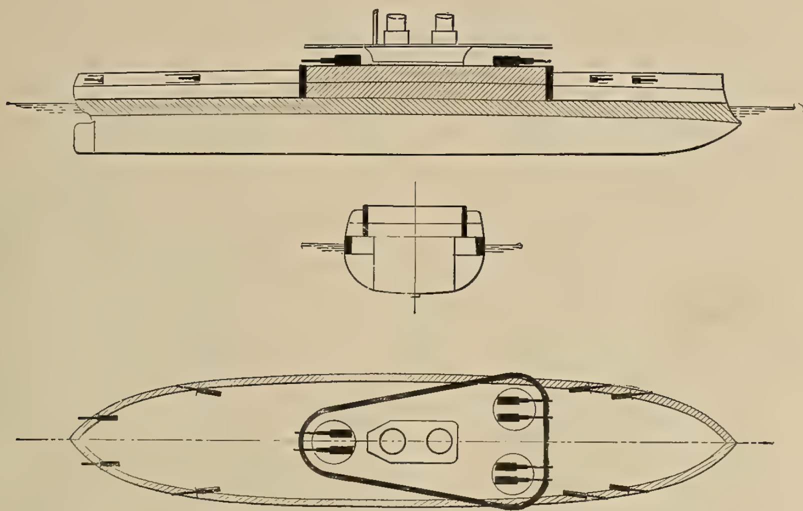


FIG. 7. "SINOPE."

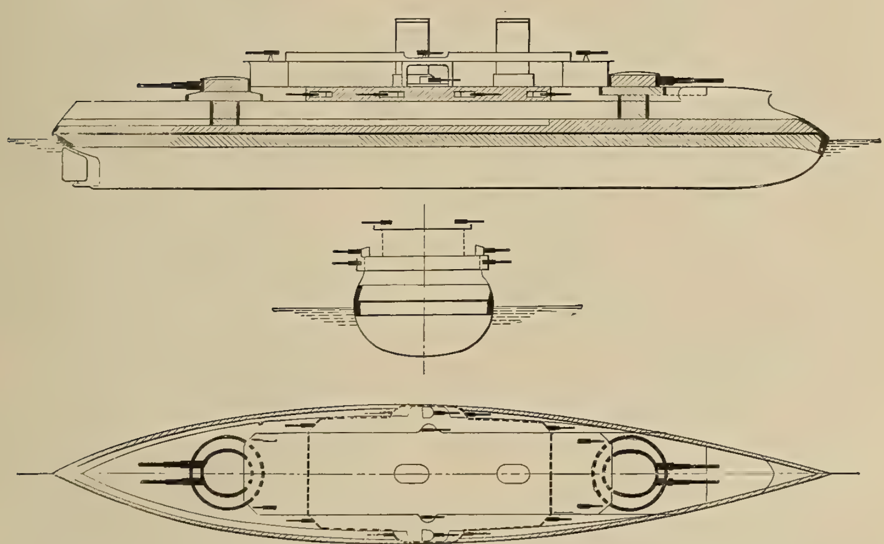


FIG. 8 "CHARLEMAGNE."

COPYRIGHTED BY MESSRS. SYMONDS & CO., PORTSMOUTH.

THE BRITISH TWIN SCREW CRUISER "ARETHUSA," DISPLACEMENT, 4300 TONS. I. H. P., 5000. SPEED, 17 KNOTS.

mechanical loading appliances, and the machinery for rotating the turrets, as well as the means of access to the ends of the ship when in action. The engines must be kept low for protection. Longitudinally there is little or no freedom. And all this arises from the fact that the fundamental idea of the type is to have a heavily armoured central citadel, of minimum possible dimensions. Even in this extreme case the difficulties were surmounted, by cordial co-operation between the naval architect in the propelling apparatus of torpedo boats, destroyers and small craft, are dealt with elsewhere. They have furnished most valuable data which are already influencing other marine engineering and will be more heard of in future.

Not infrequently it is alleged that warships cannot approach on service results attained on contractors' trials, and that they are incapable of maintaining high speeds for long periods. The suggestion seems to be that this results

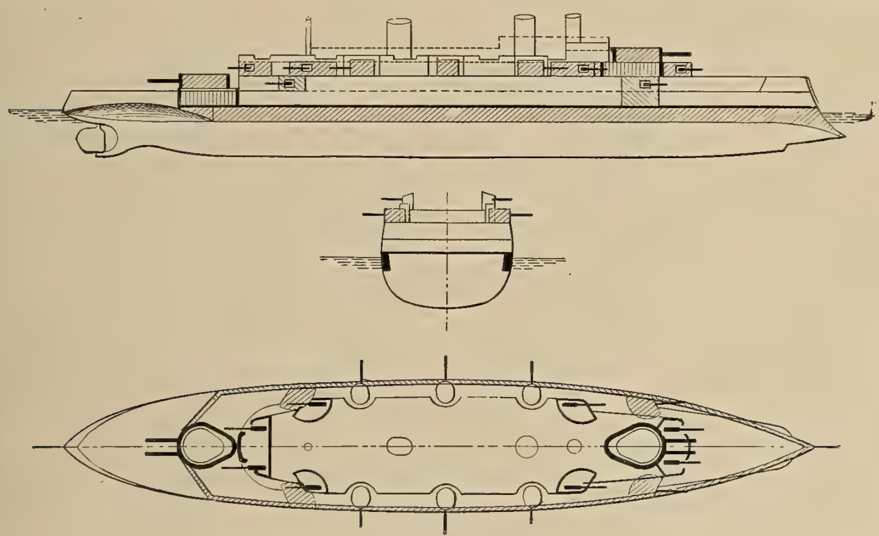


FIG. 9. "KAISER FRIEDRICH III"

and marine engineer. Upon the mutual good will and joint effort of the two professions all successful steamship construction must depend.

Some of the difficulties inherent in warship construction have resulted in experience which has been of advantage to marine engineering generally. In order to secure protection, engines have to be designed with shorter strokes, and greater rates of revolution than are usual in merchant ships. It will hardly be disputed that the success achieved with engines of this class in swift cruisers of great power has an important bearing on general practice. The remarkable results attained in the association of lightness, strength, and power from undue lightness of machinery or insufficient boiler power. There is no evidence of which the writer is aware to support the view that warship machinery is lacking in strength. That it is lighter in proportion to the maximum power developed on contractors' trials than is usual in mercantile practice is unquestionable; but that fact does not justify the suggestion of insufficient strength. Savings in weight, without sacrifice of strength, are possible and are realised by the use of superior materials, the careful design of every detail and avoidance of forms which are heavier but not stronger than alternatives, and by the higher rates of revolution above mentioned.

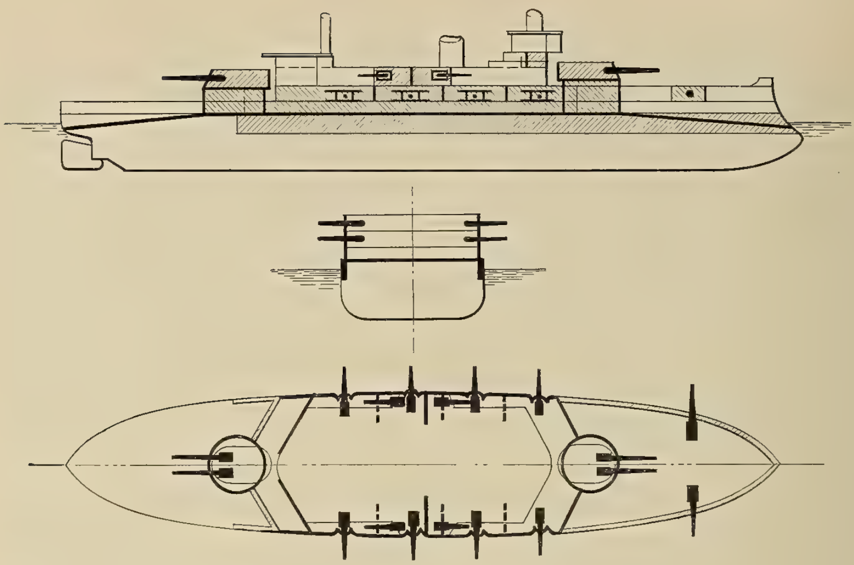


FIG. 10. "ALABAMA"

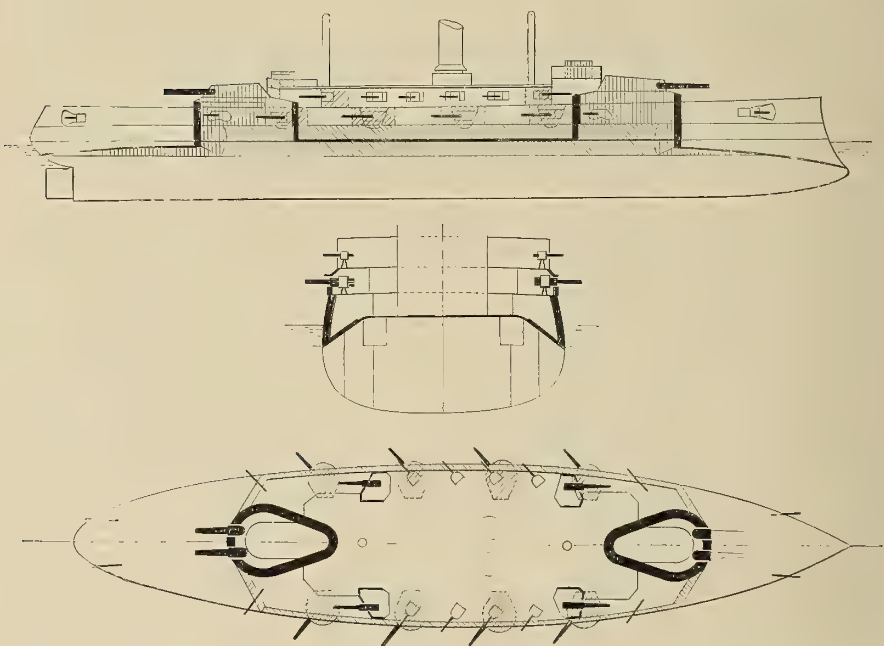


FIG. 11. "MAJESTIC."

It is, undoubtedly, true that contractors' trials are made, and are intended to be made with everything at its best. It is also true, of all steamships, that for continuous steaming at sea the development of power will not equal that obtained on trials of a few hours. No one familiar with the subject confuses measured mile speeds with continuous sea speeds. This has long been recognised in the Royal Navy. As a minimum, for cylindrical boilers 60 per cent. of the specified natural draught power is expected to be developed continuously at sea.

There are many instances where 80 to 100 per cent. of the specified power has been developed for long periods on passage trials made by H. M. ships under service conditions. The *Royal Sovereign* maintained 8100 horse-power from Plymouth to Gibralter, her specified natural draught power being 9000 horse-power. She averaged close on 15 knots,—the passage ending in bad weather—as against 16½ knots on the measured mile. This is by no means an exceptionally good performance. It is unnecessary to multiply instances. The *Powerful* and *Terrible* have so far been only tried for thirty hour runs. Their sea performances on service are awaited with interest. The writer's guarantee in the design was that they should maintain 20 knots at sea in fair weather. With 72 per cent. of their specified maximum power they have maintained 21 knots for thirty hours, and the practical certainty is that on service there will be no difficulty in fulfilling or exceeding the guaranteed sea speed.

Reference to these vessels naturally leads to the remark that recent experience with water-tube boilers has been almost restricted to warships, except in France; and there the applications of such boilers to warships far exceed in scale and importance their use in merchant ships. While recognising that English engineers have done much valuable work in this direction, it is only proper to assign to our French colleagues the greater share of credit for this new departure from which so much may be hoped. To their skill and courage is chiefly due the use of water-tube boilers in large seagoing ships, and others have benefited. This is not the place to mention, much less to discuss, the relative merits of various types of boilers. But when extended experience has shown what are the best types, it will remain on record that the advance made was based chiefly on work done in warships.

The very great range of power over which the machinery of warships is required to work on service is not paralelled in the mercantile marine, where all classes work under fairly uniform conditions of development of power, and the swiftest ships run over fixed routes. Everything in the merchant ship can be adjusted so as to most fully promote efficiency and economy under these known conditions.

In the warship it is not so. Ordinary cruising has to be done at very low powers; periodical passage trials have to be made at high powers; and in tactics or manœuvres the alternations of power may be great and rapid, as they are liable to be in warfare. As an example, take the *Terrible*. In company with a fleet steaming at 8 to 10 knots, she would require 1000 to 2000 horse-power; if proceeding at 14 to 14½ knots, about 5000 horse-power; at 21 knots, 18,000 horse-power; and at 22 to 22½ knots, 25,000 horse-power. This is an extreme case, but it indicates a condition that has to be met in all warships, and increases the difficulty of naval engineers responsible for the management of machinery.

These special circumstances also have a bearing upon the relative coal consumptions reported for mercantile and warships. Results are claimed for the former exceeding in economy those yet realised in warships under strictly ascertained conditions. It is not easy, of course, to insure exactly similar conditions in all such trials accurate determination of the indicated horse-powers, or actual weighing of the coal. Very good results have been realised in many recent ships of the Royal Navy during carefully conducted

THE BRITISH TWIN SCREW CRUISER "SYBILLE." DISPLACEMENT, 3400 TONS. I. H. P., 9496. SPEED, 19½ KNOTS.

trials extending over thirty hours. Developing from 60 to 70 per cent. of their maximum specified powers with natural draught, the coal consumption has been from 1.6 to 1.7 pounds per hour, with triple expansion engines.

Auxiliary services are multiplied in warships beyond what is common in merchant ships, and these make serious demands on their coal. Distilling, electric lighting, drilling with the heavy guns, ventilation, air compressing and other necessary operations go on even when a warship is in harbour. When cruising at low speeds this class of expenditure forms a high proportion of the total coal burnt. The matter has attracted much attention in recent years and the Chief of the Bureau of Equipment of the United States Navy published some interesting figures bearing thereon in his last report. His statement shows that only 45 per cent. of the total coal burnt in a year by the new ships of that navy was for propulsion, 55 per cent. being for auxiliary purposes. These facts are often overlooked when contrasting warships with merchant ships, in their rates of coal consumption.

In one important feature experience in warships has been of great service to the mercantile marine. The efficiency of twin screws in vessels of deep draught was first demonstrated in warships, wherein duplicate propellers were adopted, in the first place, largely on the score of greater safety when sail power was definitely abandoned.

An analysis of the relative efficiencies, as propellers, of single and twin screws was made by the writer nearly twenty years ago and submitted to the Institution of Naval Architects. On the basis of that analysis a prediction was ventured that as speeds increased in passenger steamers, it would be found advantageous to adopt twin screws, not merely for increased safety, but for economical propulsion. This opinion was not well received at the time; indeed, it was adversely criticised in some quarters. It is well known that the result anticipated has occurred. Twin screws are now adopted not merely in swift passenger steamers, but in

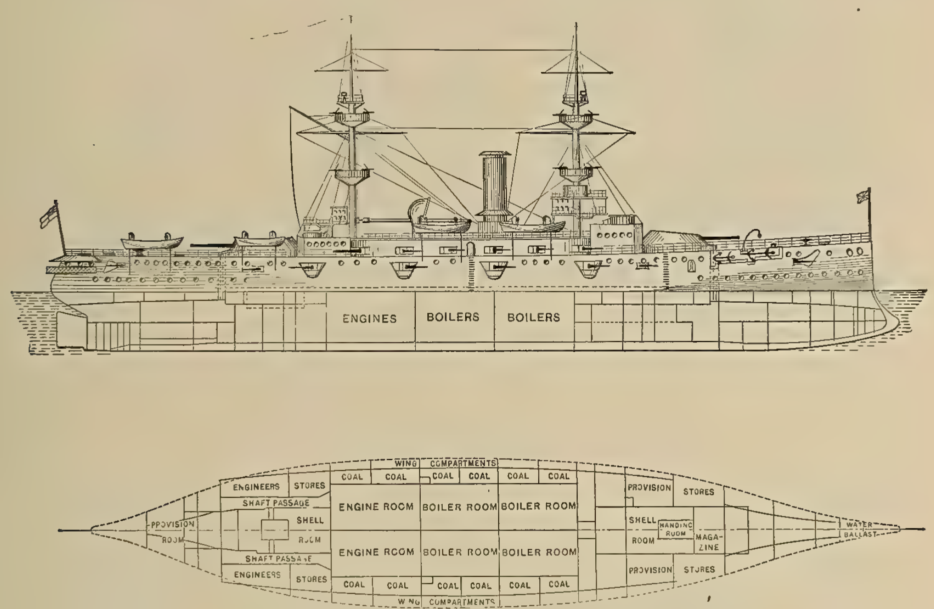
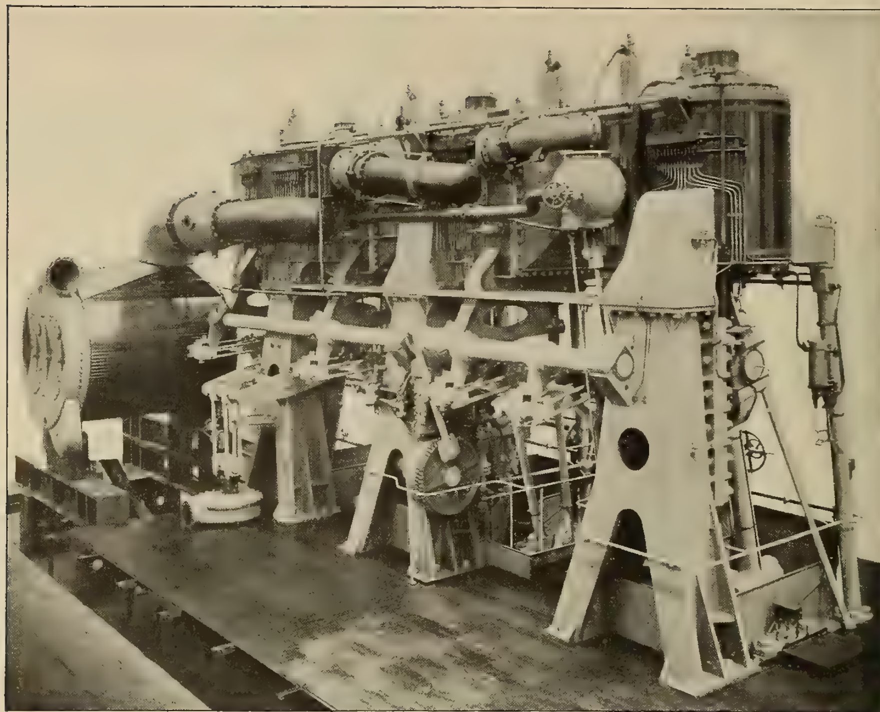


FIG. 12 A MODERN BATTLE SHIP DESIGN,



ONE SET OF TRIPLE EXPANSION ENGINES OF H. M. S. "MAJESTIC." CYLINDERS: H. P., 40 INCHES; I. P., 59 INCHES; L. P., 88 INCHES. STROKE, 51 INCHES. I. H. P. OF BOTH SETS, 12,000 BUILT BY THE NAVAL CONSTRUCTION AND ARMAMENTS CO., LTD., BARROW-IN-FURNESS, ENGLAND.

the largest cargo steamers of moderate speed.

At the present time a large number of warships built and building are fitted with triple screws. Very few trustworthy details are yet available as to the relative performances of triple and twin screws. So far as maximum powers and speeds are concerned triple screws have not proved advantageous, judging from published figures for powers and speeds of ships which can be fairly compared with one another. Other advantages are claimed for triple screws,—such as greater safety, or greater economy at low speeds. There is no doubt some increase of safety, but large experience with twin screw ships seems to show that they have an ample margin of safety. As to economy at low speeds, data from actual trials are not available. Trials appear to have been made, but the figures have not been published so far as the writer is aware.

In the Royal Navy up to the present time it has been preferred to adhere to twin screws as giving, on the whole, greater advantages under existing conditions. With the limits of draught available, high efficiency has been secured in cruisers developing 20,000 to 25,000 horse-power. In the mercantile marine similar results have been obtained with twin screws. In vessels of small size and draught in relation to their speeds, such as destroyers and torpedo gun boats, twin screws have also done so well up to date that their designers have hesitated to adopt triple screws, although alternative plans have been prepared. No doubt, the practical limitations to draught found in ports and harbours, and the further increase in speed which will inevitably be demanded, will bring about an alteration of existing conditions, favouring the use of triple screws. In that case, experience gained with triple screws in warships

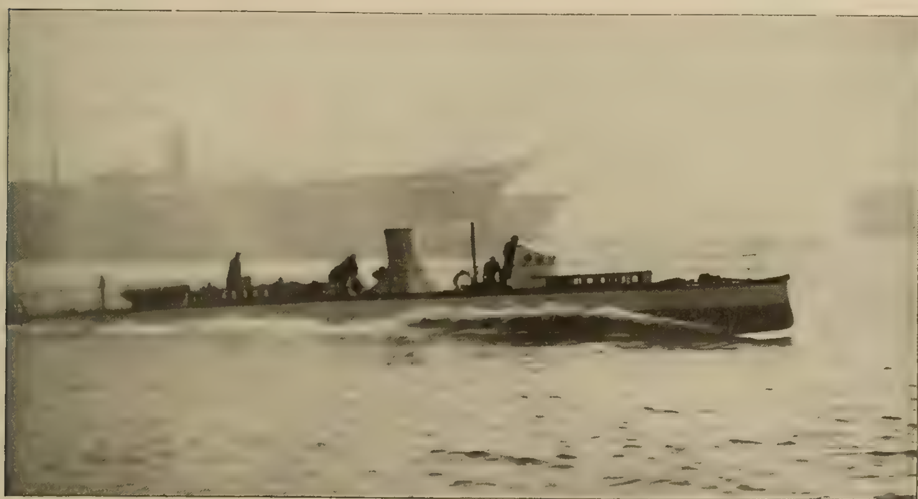
built or building, will be of immense value. There are, of course, other possible changes which will have to be considered. But it is evident that we are not yet at the end of what may be achieved.

The recent performances of the *Turbinia* are most suggestive. This little vessel, 100 feet long, 9 feet broad, and of 42 tons displacement, has been driven at a speed of about 30 knots for a short time, and the accompanying photograph was taken at that speed. Her steam turbo-motors, invented by the Hon. C. A. Parsons, revolve about three times as fast as any reciprocating engine, and to utilise their power, multiple screws of special design have been found necessary.

In structural arrangements warships furnish many examples of specialisation resulting from their employment as fighting machines. These features are most marked in battle ships. They appear to a less extent in cruisers and smaller vessels, but are never entirely absent. Systems of framing which are well adapted to merchant ships are inapplicable to warships which are armoured and protected. As a rule, warships are built of much lighter scantlings than merchant ships of equal size.

It has been asserted that lightness has been carried too far. Less has been heard of such statements in recent years; and no wonder, when it is remembered that some of the most notable examples of structural strength, under exceptionally trying conditions, have been furnished by warships. The case of the *Howe*, which struck a reef at Ferrol, tore away a considerable portion of her bilge and subsequently foundered, is so recent as to need no description. The officials of the Swedish company, to whose skill and enterprise the salvage of the ship was largely due, expressed the warmest admiration of the remarkable structural strength of the ship, to which they attributed much of their success.

It may be argued that the system applied in warships would not be well adapted to merchant ships, but it cannot be disputed that it answers well in warships, and combines lightness with ample strength. Allusion can only be made to a few of the principal features of construction to which this result is due.



THE "TURBINIA" LENGTH, 100 FEET. PROPELLED BY PARSONS STEAM TURBINES.

The hold space of a warship, as explained above, is very minutely subdivided, and each compartment is appropriated for special services. The vari-

ous transverse and longitudinal bulkheads, and the horizontal decks and platforms necessitated by these arrangements, are so constructed and stiffened as to form valuable contributaries to structural strength, besides being watertight partitions. By this means the forms of ships are largely maintained, and comparatively light framing suffices to stiffen the skins. Cellular double bottoms are adopted in all except the smallest classes, safety as well as strength being increased thereby. Double sides, or "wings" form continuations of the double bottoms to some distance above water. Intended primarily as safeguards against under water attacks, they are wrought into valuable features in the structure, as are also longitudinal coal bunker bulkheads.

In the upper portions of armoured and protected ships the requirements for defense are paramount, and structural arrangements have to be adapted in the best manner possible, so as to combine defensive features with a proper provision of structural strength. Vertical armour on the sides has to have special framing and plating behind it, in order that an efficient "target" may be formed. Material has to be massed in protective decks, so situated as to make them of small value as factors in the structural strength. Enormous and concentrated loads have to be carried high up in the form of batteries, barbettes, citadels and turrets containing or protecting the guns.

The installation of these guns often sadly interferes with ideal conditions of distributing material in the structures. Ports have to be cut through sheer strakes, or casemates built which break the continuity of strength. Portions of the sides or decks exposed to the blast or recoil of guns have to be specially thickened or supported. In endless ways the designer is checked and interfered with when endeavouring to produce a strong and seaworthy structure, capable of steaming at high speed. Provision has to be made also of weight for multitudinous fittings and accessories connected with armament and special equipment, all of which it is customary to reckon in the hull, but most of which in no way contribute to its strength.

By the use of materials of high quality, strict attention to details, good workmanship, and skill in design, excellent results have been obtained under these difficult conditions in the association of lightness with strength. Before mild steel came into use, warships were always built of tested iron having high tensile strength. Similar tests of iron for merchant ships were then rare. Mild steel was produced in 1874-5 in response to the appeal made by Sir Nathaniel Barnaby on behalf of the British Admiralty, and was used in the Royal Navy for two or three years before it was authorised by Lloyd's for merchant ships.

The cellular system, borrowed by warship constructors from the practice of Brunel and Scott Russell, was modified and improved. In its turn, it was adopted in various forms by the mercantile marine. War shipbuilding has thus, in many ways, influenced mercantile construction, although from the differences inherent in the services and treatment of the two classes, great contrasts continue to exist in many features.

Careful analyses show that in battle ships and cruisers of large size, high freeboard and great engine power, the total weight of hull accessories and fittings amounts to about 38 per cent. of the displacement. Large and swift passenger steamers have weights of hull and fittings ranging from 45 to 50 per cent. of their displacements at deep load draught, or something like 10 per cent. in excess of the corresponding figures for warships. No doubt, explanations of this difference can be given; but the relative economy in weight of the warships is notable, and the more so when it is added that only about half the weight reckoned into "hull" for warships primarily contributes to the structural strength.

Many reputed authorities on ship construction, after inspecting warships on the stocks, have unhesitatingly condemned their excessively light scantlings, and predicted disaster. We have been told, again and again, that ships

would "buckle up their bottoms," or "shake themselves to pieces," or "never come off again if they grounded," or, in some other fashion, "come to grief." Unfortunately for the prophets these things have not happened. Ships thus condemned have remained in service for twenty or thirty years; have gone aground and been severly damaged locally, but have been got off and readily repaired; have given no evidence of structural weakness.

Proper care must be taken in their maintenance, cleaning and painting in order to prevent corrosion of their thin plating. Simple precautions, which are mere matters of routine, must be observed in launching or docking, especially with armoured ships. But no one will now venture to dispute that, on the whole, the special methods adopted in warship construction have been proved successful, or that the economies effected are most valuable.

There is one feature of construction in which warships stand alone at the present time. They are often sheathed with wood over the steel skins, and coppered in order to keep the sea for long periods without serious foulness of bottom and consequent loss of speed. For fully thirty years this practice has more or less prevailed in the Royal Navy. It has been imitated in other navies, and largely so by the Russians. About ten years ago the writer introduced a simplified form of sheathing which has proved completely successful, and during the subsequent period a very large proportion of the cruisers built, as well as some battle ships, constructed for distant foreign service, have been sheathed and coppered.

Ships built on this plan have ample strength, quite independently of the wood sheathing. It constitutes a safeguard and additional protection, no doubt, in case of grounding. Additional first cost is involved, and somewhat greater displacement. Experience proves, however, that the power of maintaining clean bottoms and full speeds, without docking, amply compensates for these disadvantages. The system is not likely to find favor in merchant ships, whose frequent visits to ports give ample facilities for docking and cleaning at moderate cost.

Special and difficult problems relating to stability arise in connection with warship design. The same principles, of course, govern the stability of all ships, and it is now recognized to be necessary to investigate the actual conditions of stability for all novel types of merchant ships. But the vertical distribution of weights in warships differs radically from that in merchant ships, and freeboard, as has been shown above, is determined by the fighting qualities, rather than by considerations of lading. Passenger steamers naturally have high freeboard for purposes of accommodation, and there is usually no question of their range of stability in seagoing condition, provided they are given sufficient "stiffness." They usually carry relatively small cargoes, low down in the holds, and if they became "tender," as coal is burnt out, water ballast can be used to restore stiffness.

Steamers carrying large cargoes necessarily have larger variations in their stability at different periods, according to the weight and character of the cargoes on board. Under existing conditions, with fixed load lines, one of the conditions kept in view when determining those lines, is the provision of sufficient stability under the least favourable conditions of loading likely to occur. In no merchant steamer, however, from the nature of their service, do conditions of loading occur similar to those in warships.

Broadly speaking, the essential difference between merchant ships and warships is that the former are designed to carry their loads, or principal portions thereof, low down in the holds, whereas warships have to carry heavy burdens of armour and armament high up on their sides. The centres of gravity of laden warships are consequently much higher relatively to the depths of the ships than the centres of gravity of merchant ships, and this fact has an important bearing both on initial stability, or stiffness, and on range of stability.

Methods of calculating the stability

THE BRITISH TWIN SCREW CRUISER "POWERFUL." DISPLACEMENT, 14,200 TONS. I. H. P., 25,000. SPEED, 22½ KNOTS. BELLEVILLE BOILERS.

of ships and experimentally verifying the results were devised a century and a half ago. Little use was made of these methods, however, until about thirty years ago. Occasionally, an "inclining experiment" was made to determine the actual position of the centre of gravity of a warship, and the usual calculations connected with designs fixed the position of the metacentre for transverse inclinations. But so long as sails continued to be used, and high freeboards maintained, the ordinary procedure was to consider the stability to be satisfactory, if ships in service proved sufficiently stiff to carry their sail-power with moderate angles of keel. Long experience had justified this procedure, and subsequent investigation has confirmed it.

In some cases the sail-carrying power of completed ships proved insufficient, and then recourse was had to methods of increasing stiffness by adding ballast, placed low down in the holds, or by girdling the water-line region with thick planking in order to increase the breadth and raise the metacentre. These practices are centuries old and not yet entirely out of date, even in these days of scientific method.

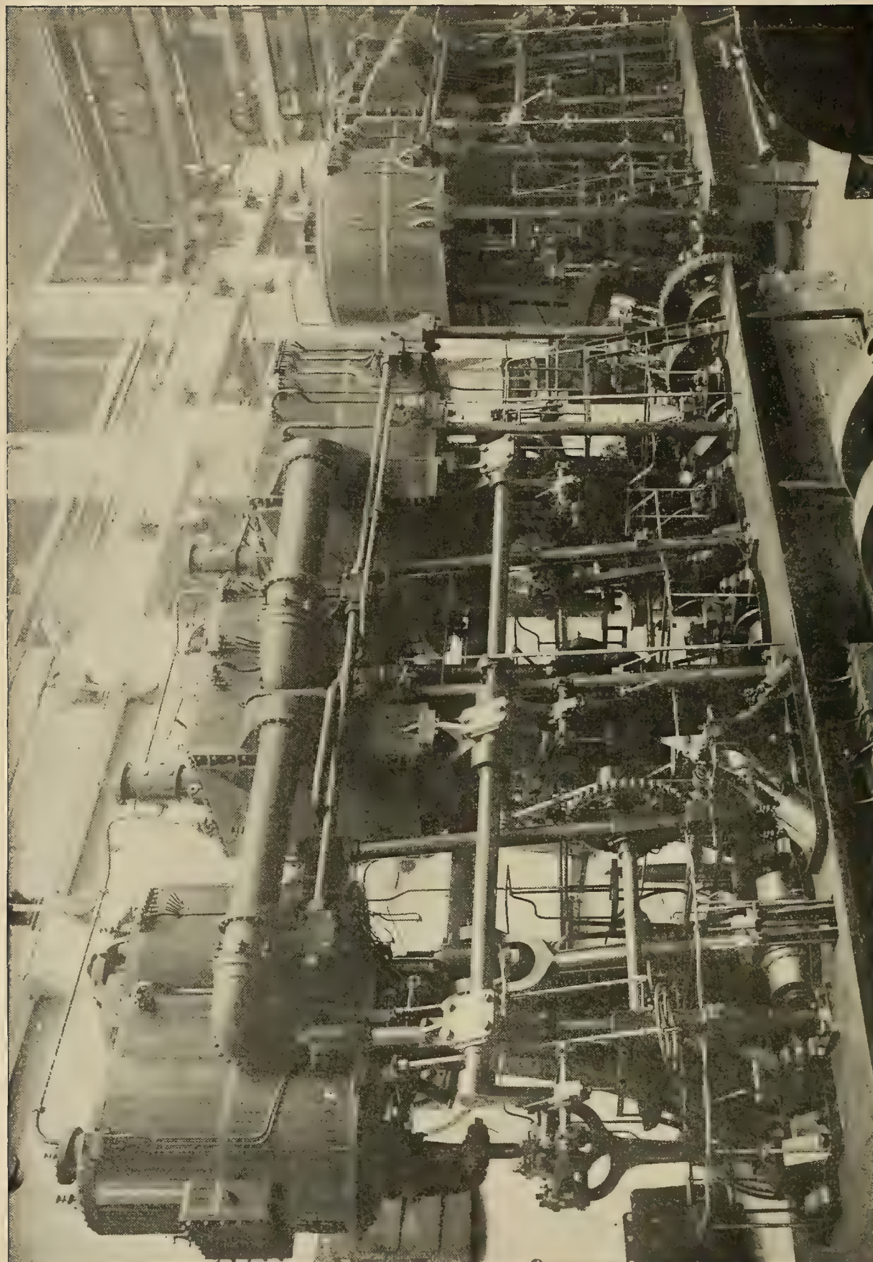
When vessels were proposed and constructed with good sail-power, but low, or very moderate, freeboard, it became apparent that more thorough investigation of their stability was required, not merely for small angles of inclination to the vertical, but to determine how righting power varied as inclination increased, and at what inclination ships would become unstable.

The first calculations of this nature, and the earliest curves of stability on record, were made at the British Admiralty in 1867 by the late Mr. W. John and the writer at the suggestion of Sir N. Barnaby, who was then one of the principal assistants to Sir Edward Reed, Chief Constructor of the Royal Navy. It was thus demonstrated that particular types of ships became unstable at very moderate angles of inclination, although they were possessed of ample stiffness for small inclinations. Three years later, the loss of H. M. S. *Captain* furnished a terrible illustration of the practical importance of these deductions from scientific investigation. Hence resulted the establishment of the system of complete calculations for stability of all types of warships in connection with their design, and of experimental verification of the actual positions of the centres of gravity of completed ships. The work is laborious, of course, and requires great care. It is much assisted by the fact that the actual weights of material built into the hulls and fittings of warships are now commonly ascertained and recorded for future reference. Consequently, accessories and fittings for which the weights would be difficult to calculate may now be dealt with readily and accurately. These constitute, as has been stated above, a very considerable portion of the reputed weight of hull.

In competent hands such methods of calculation yield results which are remarkably accurate for the most novel types. Two examples may be given from the writer's recent practice. The *Royal Sovereign* has a load displacement of 14,150 tons. Calculations for her included hundreds of items. When completed, it was found that the actual and estimated weights practically agreed, while the centre of gravity was about two inches lower than had been estimated. Equally close agreement was proved to exist between estimate and result in the case of the *Terrible*. Both these types were entire departures from precedent.

In choosing dimensions and proportions for warships, stability exercises a preponderating influence, and this chiefly in the relation of breadth to draught, and depth. The problem to be solved is not the discovery of a theoretical form of least resistance, but of the form best adapted to the set of conditions laid down to be fulfilled in the design. Those conditions embrace armament, protection, speed, coal endurance and draught. They vary greatly in different classes and lead to very different solutions.

In any particular case, what has to



THE ENGINES OF H. M. S. "MARS" IN MESSRS. LAIRD BROS.' ERECTING SHOPS AT BIRKENHEAD. I. H. P., 12,000.

be determined, as far as possible, is the form which will be most economical in size, cost, and propelling power combined. It is possible to obtain economy in propulsion by changes which involve such increase in weight and cost of hull and protection as to far outweigh that economy. On the other hand, it may prove that the form which gives favourable results in propulsion and other respects is inadmissible, because it does not afford sufficient stability. Each case must be dealt with independently and thoroughly.

Criticisms of the forms and proportions of warships are very common, in which their great relative breadths and moderate lengths, as compared with merchant ships, are chiefly complained of. "Greater length and less beam" is a favourite formula. No one familiar with ship design and propulsion will question the advantages, in regard to the attainment of high speeds in association with good carrying power, obtainable by increase in length. But in warships increased length means decreased handiness and increased weight of protection, and all these effects require to be considered.

That increased beam and larger areas of immersed midship sections are prejudical to speed was a doctrine once very widely accepted. Scientific and experimental investigation, and experience with actual ships, have disposed of this doctrine completely. In fact, increase of beam and immersed midship section have often resulted in considerable economies of engine-power, when other changes of form have accompanied such increase. Greater length favours maintenance of speed at sea, and for swift passenger steamers, running on fixed routes, at uniformly high speed, this feature is, undoubtedly, of considerable importance. Warships are not built for such services and in most instances, — excluding torpedo craft, — their lengths are ample in relation to their maximum sea-speeds.

As speeds have increased, so have lengths been increased. First-class battle ships, built twenty years ago, with maximum speeds of 14 to 15 knots, had lengths of 300 to 330 feet. Battle ships of the present day, with maximum speeds of 17 to 18 knots, have lengths at the water-line of 380 to 410 feet. Cruisers, with speeds of 20 to 22 knots, have corresponding lengths of 450 to 520 feet In some quarters whatever length may be decided on, it is pronounced to be "50 feet too short," as a rule, without any investigation of what such an addition would involve. Where criticisms have been associated with alternative proposals,—and such cases are few,—it has been the writer's task to investigate them. In no single case so treated has it appeared that the proposals made would have given the gains in propulsion anticipated, in association with other supposed advantages. As a rule, the proposals made have been proved to be incompatible with a due provision of stability.

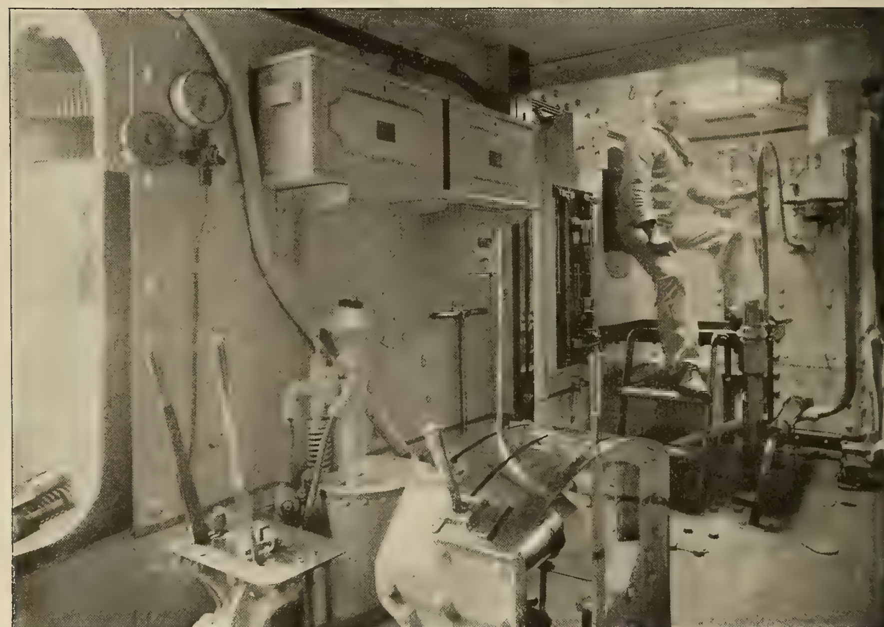
Any one not intimate with the conditions of stability in warships may be disposed to think that if battle ships or cruisers possess high-freeboard and sufficient stiffness, all other conditions of stability will be satisfied completely. This is by no means true. Types of warships are in existence with high-freeboards and all the stiffness thought necessary by their designers for ordinary service, but in which the area and range of their curves of stability are much inferior to the corresponding features of a monitor of the Ericsson type, with a deck only three feet above water.

Warships are no longer distinguished from merchant ships by greater size, as they were in the earlier half of this century. The sizes of both classes have been enormously increased during the last forty years, but the rate of growth has been greater in the mercantile marine, measuring it by the dimensions of the largest ships afloat. The largest battle ships of 1857 were three-deckers of 7000 tons displacement. Our first seagoing iron-clad, the *Warrior*, of 1859, was about 9000 tons; the *Minotour*, of 1861, was 10,600 tons. Then came a reaction in favour of more moderate dimensions, in association with the use of the "belt and battery" system, and first-class ships had displace-

ments of 8000 to 9500 tons from 1865 to 1871. Then larger displacements of 11,000 to 12,000 tons were adopted, to be followed by a return to 9500 and 10,500 tons in ships built between 1878 and 1883.

In 1886 battle ships of 12,000 tons were laid down; in 1889, of 14,000 tons; and lastly the *Majestic* class, in 1894, of 14,900 tons. Foreign battle ships have also grown in size. The *Italia* and *Lepanto*, of the Italian Navy, have deep-load displacements of nearly 15,000 tons; the *Sardegna* class, of nearly 14,000 tons. The largest French and Russian battle ships are of 12,000 to 12,500 tons; and the latest German ships exceed 11,000 tons. Japan has followed suit with ships of 12,500 to 15,000 tons.

The growth in size of cruisers has been still more remarkable, especially during the last ten years. The largest unarmoured screw frigates of 1857 were 5600 tons displacement. In 1887 the largest unprotected cruiser in the British Navy was of 6250 tons, and the largest protected cruiser was less than 4000 tons. In the French Navy nearly the same limits of size were then found, under 6000 tons for unarmoured cruisers, and about 4200 tons for protected cruisers, with two exceptions where 6000 to 7000 tons had been reached. A new departure was taken in 1888 when the *Blake* and *Blenheim*, of 9100 tons, were laid down, to be followed, in 1889, by the *Edgar* class, of 7400 to 7700 tons, and in 1893 by the *Powerful* and *Terrible*, of 14,200 tons.



IN THE BARBETTE OF H. M. S. "REPULSE."

In other navies the same course has been followed. Russia has her *Rurik* and *Rossia*, of 11,000 to 12,100 tons. France has the *Jeanne d'Arc* class, of 11,300 tons; Germany, the *Ersatz Leipzig*, of 10,650 tons; the United States, the *Brooklyn*, of 9250 tons. This growth of size has been accompanied by great increase in speed, coal-endurance, armament and protection.

What is here desired, however, is not to trace this growth in detail, but to bring into relief the fact, which is often overlooked, that, large as are the

ON THE FORECASTLE OF H. M. S. "SANSPAREIL."

dimensions of first-class battle ships and cruisers, they are inferior to those of the largest merchant ships in length and load displacement. Different modes of tonnage measurements confuse the comparison. "Tons of displacement" are not comparable with "registered tons,"— the common measure used for merchant ships. The gross tonnage of ocean-going steamers may vary from one-half to two-thirds of the load-displacements. The "net" or "registered" tonnage of steamers of high power and great speed may be only 44 to 54 per cent. of the gross tonnage, and so may be as little as one-fourth of the load-displacement. It will be seen, therefore, how misleading may be mere superficial comparisons, such as are frequently made between merchant ships and warships.

Taking load-displacements as a means of comparison, the largest mercantile steamers afloat exceed the largest warships by fully 30 per cent. Both passenger and cargo steamers now afloat are said to have displacements of 20,000 tons or more. Taking lengths, the longest merchant ships exceed the longest battle ships by about 200 feet, and the longest cruisers, by about 100 feet. Taking maximum draughts of water, there is probably no great difference. In beam, for reasons explained above, the warships have a considerable excess.

In view of facts such as these, the absurdity of the designation "monsters," as applied to modern battle ships and cruisers, will become apparent. Growth in dimensions of merchant ships is usually a matter of admiring comment. The less rate of growth in warships is frequently a matter for adverse criticism. Similar causes compel the adoption of greater dimensions in both classes.

It may be fairly assumed that no ship will be made larger than she requires to be for her intended service, and that there are good reasons why merchant ships have outgrown warships. Every one familiar with the designs of both classes must admit that more is required to be "done on the dimensions" in warships than in merchant

ships. In other words, warships are more moderate in dimensions in proportion to the loads carried and speeds realised. If mercantile practice were followed in hulls, engines and boilers, warships would have to be considerably enlarged.

Simply for purposes of illustration, and not as any indication of comparative skill in design, it may be stated that in a cruiser of the *Powerful* type the load carried in the form of armament, equipment, protection, sheathing and coals exceeds the load of coals and cargo which would be carried by a passenger steamer of equal displacement tonnage and equal sea speed, by something like 2000 tons. This economy results from many causes, amongst which the adoption of water-tube boilers deserves mention. But space does not admit of a full analysis.

Nor is it proposed to discuss, at any length, the reasons why British warships of the present day are, as a rule, of larger displacement than foreign warships which are supposed to be their equals in speed, armour and armament. The writer has been charged with having a leaning to large dimensions for their own sake. This is not a charge that need be dealt with, beyond the statement that it has yet to be shown that the same conditions which have been fulfilled in ships of the Royal Navy, built during the last twelve years, can be, or have been, fulfilled anywhere in vessels of smaller dimensions.

Her Majesty's ships have embodied in their designs, supplies of coal, ammunition and stores such as are considered necessary by the proper authorities. These supplies are in excess of what the authorities of other navies deem necessary. Hence, there is a considerable increase in load, and a consequent increase in displacement. To carry a heavier load at a given draught and a specified speed, as every one familiar with ship designing knows, involves a much greater increase in displacement than is represented by the increase in load. As an example, reference may be made again to a comparison between an English and a foreign battle ship. The former had an excess of load aggregating fully 1600 tons, and her displacement was consequently 2300 tons greater,—not an unreasonable difference in proportion to the greater load.

Each navy has its own usage and its own views of the best distribution of weight under the several heads of armament, protection and equipment. It is mischievous and misleading to base comparisons on mere tabulated statistics without a close analysis of facts. Ordinarily, the complete information for making this analysis is wanting. Space prevents more than the briefest allusion to the errors arising from this circumstance. Take, for example, the feature of armament and its protection. Usually, the list of guns carried is given, with no details of protection or supplies of ammunition. What this may mean will appear from the following facts:—

For the same total weight it is possible to have, (1) a single 6-inch quick-firer with 200 rounds of ammunition, and complete protection in the form of a turret or casemate; (2) two guns with about the same ammunition per gun, and simple shield protection; (3) four guns with about half the ammunition per gun and light shield protection.

In tables such as are commonly given, the third plan would loom large, and the first would appear greatly inferior. But it probably would not be so in the day of battle. At all events, the comparison, as usually made, is partial and misleading; and from the point of view of the naval architect the weight to be carried in each case is the same whichever plan is adopted. British ships have their secondary armaments well-protected and have large ammunition supplies.

Under the head of protection, too, fallacious comparisons are often made, the favourite method being to compare only maximum thicknesses of armour, without reference to areas protected, or weights devoted to protection. One ship may have a narrow belt, rising less than two feet above water, and 16 to 18 inches thick for a depth of three or four feet. She is credited with the maxi-

mum thickness as her measure of protection, although huge superstructures, containing or supporting the secondary armaments are altogether unprotected. Another ship may have an equal weight of armour distributed uniformly over a much larger area, and rising 10 feet above water. But the maximum thickness may be only one-half that on the first ship, and the common method gives her that comparative protection. There is here also room for difference of opinion as to methods of protection, but if the weight of protective material is the same, the task of the naval architect is not sensibly different in the two cases. If merit according to tabulated statistics were the chief end in warship design, many things might be done which would count in such imperfect comparisons, but would certainly not add to real efficiency.

It is needless to multiply illustrations of this kind. What has been said is enough to show that only the closest comparison between the qualities of ships can enable fair relative values to be assigned to them, or differences in size explained. Further, the naval architect has not the decision of these important matters in which the practice of various navies differ. He has to embody the conditions laid down for his guidance in a design.

The writer's conviction, based upon a somewhat large experience both in the Royal Navy and outside it, is that at any given period, if the conditions of the problem were stated in identical terms to the leading warship designers of the world, the results obtained would not differ greatly as regards the sizes of ships proposed to fulfill the conditions. Differences in proportions and forms there would be, no doubt. But the differences that exist in dimensions of existing warships, in comparable classes, must be chiefly assigned to differences in the conditions laid down to govern the designs. Any improvements which may be originated in one country in materials of construction, marine engineering, gunnery, torpedoes, explosives or armour do not, and from the nature of the case cannot, long remain solely in the hands of its originators. There is no monopoly of invention or technical skill. What has been accomplished in one country will speedily be rivalled, or perhaps temporarily excelled, elsewhere.

In conclusion, brief reference may be made to the costs of warships. The cost of building ships and their machinery varies greatly in different countries, for reasons that cannot now be discussed. At the present time, no doubt, the most economical production can be secured in Great Britain. Probably, as experience in other countries is enlarged and the industries developed, differences in costs will be diminished. Home-production of warships will be favoured in all countries for obvious reasons, even if it involves greater cost. The action of the United States in the reconstruction of its navy during recent years affords the most remarkable example on record of what can be accomplished by determined and well-directed effort. All great maritime countries are moving in the same direction.

Growth in dimensions, speeds, protection and armament has necessarily been accomplished by increase in cost. In 1637 the *Sovereign of the Seas* cost about £41,000, half of which was for labour. This was quite an exceptional outlay, and, no doubt, other than legitimate expenses were charged against that vessel. At the beginning of this century a 100-gun line-of-battle-ship cost from £65,000 to £70,000, exclusive of armament. The 121 gun sailing three-decker of 1837 cost nearly £120,000, and the screw three-decker of 1857, about £220,000.

The use of armour added greatly to the cost, and the *Warrior*, of 1859, figured up nearly £380,000. The *Dreadnaught*, of 1873, cost £620,000, and the *Inflexible*, which followed her, cost £810,000. These large amounts were partly due to the introduction of costly mechanisms required for mounting and working the heavy guns, and partly to large increase in the outlay on armour.

Then came the reaction in favour of less costly ships, and vessels were

produced for £600,000 to £650,000, between 1875 and 1885. The inevitable tendency reasserted itself in 1885, the *Nile* and *Trafalgar* each costing about £850,000. The *Royal Sovereign* class of 1889 cost about £775,000, and the *Majestic*, about £840,000. All these figures are for ships built in the Royal dockyards, and exclude incidental charges as well as cost of armaments. They include gun mountings with their costly mechanisms, and torpedo gear.

Cruisers have similarly increased in cost. The *Blake* cost about £440,000, or about twice as much as the unarmoured cruiser *Inconstant*, laid down in 1866. The *Powerful* will cost about £680,000. She carries a considerable weight of expensive armour, and gun-mountings costing over £50,000.

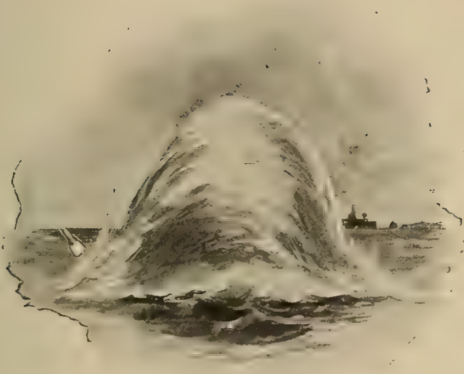
Other navies spend even more on their units of naval force. A French first-class battleship costs about £1,000,000; and so do the corresponding ships in the Russian and Italian fleets. The American battle-ship *Indiana* cost over £600,000, exclusive of armour, and that involved an expenditure of nearly £340,000. For the German battle-ships now building, of about 11,000 tons, the estimated cost is about £700,000. It will be seen, therefore, that British battle-ships are, in proportion to their dimensions, less costly than battle-ships of other navies, and actually less costly than most foreign battle ships of about the same date.

The same thing may be said of cruisers. The French *Jeanne d'Arc* is estimated to cost about £800,000; a German first-class cruiser, about £650,000; and the American *New York* cost, exclusive of armour, etc., about £600,000. The actual costs of the great Russian cruisers are not known, but must reach high figures.

As compared with the costs of the largest passenger steamers the foregoing figures no doubt will appear very large. But if deductions are made for the expenses incurred on armour, gun-mountings and mechanisms, torpedo gear and special fittings, representing together, say, £350,000 to £400,000 in a first-class battleship, the comparison is made fairer, and the warship approximates in cost very closely to the largest passenger steamers.

FAST TORPEDO BOATS.

By A. F. Yarrow, M. Inst. C. E.



EXPLOSION OF A TORPEDO CONTAINING 67 POUNDS OF GUN-COTTON.

IT is extraordinary that an impression prevailed for some time that the torpedo boat was a cowardly kind of craft, seeking destruction of the foe by insidious means and hardly to be classed as a weapon of honest warfare. Putting aside the question whether offensive warfare, as some assert, is, in reality, anything less than robbery on a large scale, it does seem strange that an artilleryman, behind ten or twenty feet of earthwork, hurling explosive shells at an almost unseen foe, should be held as fighting fairly, while in the case ot the torpedoist, who has the pluck to accompany his missile to within a short distance of his enemy, it should be considered an unfair mode of attack.

The first idea of a torpedo boat was primitive enough,—a few sailors in a rowing boat, daring death in the darkness of night, carrying an explosive bomb at the end of a pole, bringing it into contact with the enemy's ship, and then pulling out of harm's way as fast as they could. As an early example of a torpedo boat attack may be mentioned the foundering of the United States man-of-war *Housatonic*, destroyed in 1864, by a rebel torpedo boat, which did its work so effectually that it was sucked into the breach made by the explosion and itself sunk with all hands. As an early torpedoist the name of Captain Hunter Davidson stands pre-eminent. This officer attached himself to the Confederate side during the Civil War in the United States, and his feats are now matters of history.

The author must here point out that in writing on this subject the only course open was to describe experiments carried out, and results obtained, by his own firm, as it is of these alone that he can speak with authority.

The great advance in speed of late years has been due to the efforts of a few distinguished men, among whom should be mentioned Messrs. Thornycroft and Monsieur Normand. It must not, therefore, be inferred that, by confining himself to the work done at Poplar, the author does not fully appreciate and recognise what has been done elsewhere.

The first launch designed specially to act as a high-speed torpedo boat was, probably, built at Chiswick, in 1873, and in 1875 the author's firm constructed one for a South American power. The latter was fitted with a pole for carrying a torpedo at its forward extremity. The speed of this craft was 13 knots. Before being shipped it was desired by the government which purchased the vessel to illustrate its utility and to ascertain how much the crew and the launch would be endangered by the torpedo being exploded under an enemy's vessel.

This was practically tested by blow-

ing up a barge on the Upper Thames, the result of which was that the crew, who were at a distance of some twenty feet from the torpedo, were subjected only to a shower bath on a large scale, being otherwise none the worse for their exploit. The effect of the experiment was to send the barge to the bottom and raise the ire of the Thames conservancy, who naturally objected to such an outrage being committed upon the dignity of Father Thames.

In 1877 the *Lightning*, a torpedo boat 86 feet in length, was built by Messrs. Thornycroft & Co. for the British Government, and a speed of 18½ knots was obtained. In the same year the Russian Government ordered no less than 110 torpedo boats, 75 feet in length. These were built from designs of Messrs. Yarrow & Co. The successful carrying out of this large contract was due mainly to the late Captain Kasy, who was then the head of the Baltic Works, at St. Petersburg. The speed of these vessels averaged about 17½ knots.

Following the British and Russian Governments, demands were rapidly made by naval authorities from all parts of the world for vessels suitable for carrying torpedoes. A great impetus to the attainment of high speeds was thus given, and it soon became evident that the direction in which high speeds could be obtained was by adopting the lightest scantlings for the hull, the development of the greatest power in the engines for a given weight, and getting the maximum evaporative efficiency from boilers. At about this time improvements in the manufacture of steel permitted a great reduction in the weight of the hull to be made, and the same cause enabled lighter engines to be constructed. Owing to the reduced weight of the moving parts, a high number of revolutions per minute was rendered practicable.

The introduction of forced draught also permitted an increased rate of combustion, and greater power was, therefore, obtained from a boiler of given weight. It should here be remarked that the name of Stevens (one of the

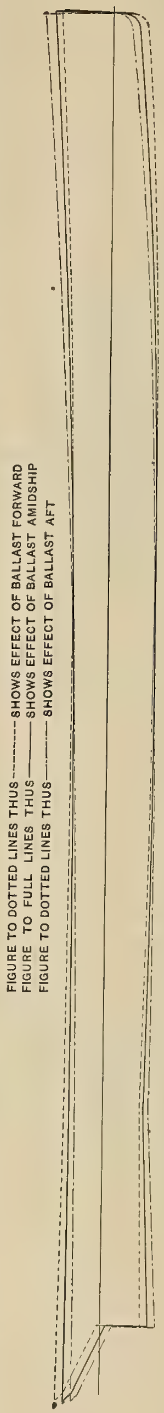


FIG. 1. DIAGRAM SHOWING TRIM WITH A LOAD OF 3 TONS IN DIFFERENT POSITIONS. TOTAL DISPLACEMENT, 33 TONS.

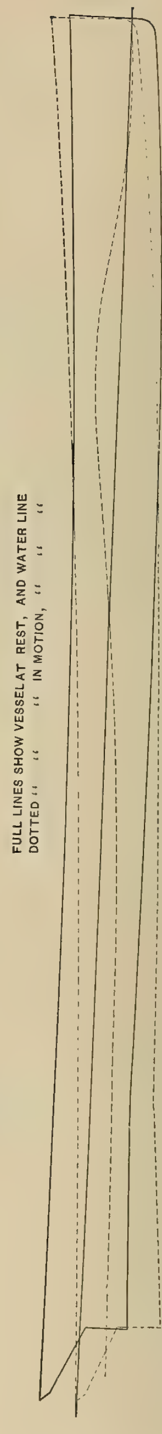


FIG. 2. DIAGRAM SHOWING ALTERATION OF TRIM AND FORM OF WAVE IN CONTACT WITH SHIP'S SIDE. DIMENSIONS OF BOAT, 85 FT. X 10 FT. 10 IN. SPEED, 20 KNOTS.

founders of the Stevens Institute in the United States must not be forgotten as being on the roll of the pioneers of the forced draught system.

In the year 1877 the Russian Government ordered from Messrs. Yarrow & Co. two first-class torpedo boats. These vessels, on trial, gave a speed of from 20 to 21 knots. Owing to a Russian scare these boats were not allowed to leave England, and were purchased by the British Government, figuring conspicuously at the naval review in the Solent in 1878. It was on one of these that the Prince of Wales made, for the first time, a trip afloat at such a high speed.

With a view to obtain data on the best distribution of weights in these high-speed vessels, the author would here refer to some interesting experiments which his firm made with one of them, having the ballast placed in different positions, the indicated horse-power being maintained as nearly as possible the same in all cases. In one trial a weight of three tons was placed near the bow; in another it was placed amidships, and in a third, at the stern. There were also other positions, but as aft; in the second case the draft of 2 feet 10 inches was uniform throughout; and in the third the draft was 2 feet 4 inches forward and 3 feet 4 inches aft. These variations of trim, it will be seen, are very large for a vessel of only 86

	BALLAST FORW'D	BALLAST AMIDSHIP	BALLAST AFT
SPEED	KNOTS 18.640	KNOTS 18.365	KNOTS 18.408
DRAUGHT; FOR'D " AFT	3'4" 2'4"	2'10" 2'10"	2'4" 3'4"
I.H.P.	417	405	395

feet in length. Fig. 1 should be referred to, showing outlines of the vessel, trimmed respectively as indicated.

The practical result of these trials was to show that it mattered little where the ballast was placed. The moral to be drawn from this is that with fine-lined vessels of this class a very large variation in the form is permissible without any appreciable difference in result,—a fact which was quite contrary to the general opinion held at that time.

In connection with these trials further experiments were made to ascertain the

FIG. 3. A SPANISH TORPEDO BOAT WITHOUT FUNNELS.

the results obtained with these confirm those now referred to, they need not be further mentioned.

These different positions of the ballast gave, in the one case, a draft of 3 feet 4 inches forward and 2 feet 4 inches

exact form of the waterline in contact with the ship's skin when running at a high speed. To illustrate this, reference should be made to Fig. 2, the full lines showing the vessel at rest and the dotted lines when in motion. The re-

FIG. 4. AN ITALIAN BOAT WITH FUNNELS DOWN.

markable alteration in trim caused by the speed will be seen, and although what is termed "sitting down aft" is very defined, it leads to a somewhat false impression, for though the vessel sinks at the stern and rises at the bow, its relation to the waterline actually in contact with the hull is not such as is apparent when viewed from the shore. The vessel is running, as it were, up hill on its own wave.

This alteration of trim is, no doubt, due to the upward pressure of the water at the forward part of the boat, coupled with the reduction of pressure at the stern, owing to the water which is displaced not following up with sufficient rapidity. The effect on the forward portion of the boat as regards alteration of trim is more apparent with vessels having a *V* shaped bow than when a *U* shape is adopted.

Owing to the fact that torpedo attacks are generally made at night, it was soon found that the issuing of flame and smoke from the funnels was a serious drawback, this being the first evidence of an approaching vessel. With a view to overcome this, Messrs. Yarrow & Co. built several vessels without funnels, the gases from the boilers issuing at each side, or, rather, on the one side or the other of the hull, dependent upon the direction of the wind. Fig. 3 illustrates one of these boats. Possibly sufficient attention has not been given to this matter. It may be that the inconvenience caused by the smoke to those on deck

FIG. 5. THE SAME BOAT WITH FUNNELS UP.

when practicing in time of peace has militated against the adoption of the plan.

In Figs. 4 and 5, the arrangement is carried out in a modified form, the funnels being either upright or inclined over the vessel's side, as may be desired. Fig. 3 shows the pole at the bow, on the end of which is fixed the torpedo. It consists of a metal case containing a highly explosive substance, such as gun cotton or dynamite, which is fired, either by contact or by electricity, at the moment of impact.

We now come to the marvellous automobile torpedo, brought out by Messrs. Whitehead. This weapon is cigar-shaped in form, and will travel under water at any required depth, for a considerable distance and at a high speed. Messrs. Whitehead's latest type has a speed of 32 knots when running 450 yards, and from 28 to 29 knots when running 900 yards. These torpedoes are usually set so as to travel at a depth below the surface of the water of about ten feet, and, if in good order and discharged properly, maintain a very nearly straight course.

Owing to the introduction of the Whitehead, the spar torpedo, except for launches, is now a thing of the past. The former is sometimes discharged from the bow (one or two bow tubes being fitted), and sometimes from revolving tubes on deck, from which the torpedoes can be discharged at various angles to the line of keel. These deck tubes are shown in Fig. 6. The torpedoes are shot out of the tubes by means of either compressed air or gunpowder. In discharging the bow torpedo, the method is for the boat to dash straight at the enemy's ship until within a few hundred yards, to stop and discharge the torpedoes, and then to get away as quickly as possible. This plan is in some navies becoming obsolete, as it leaves the boat too much exposed to the fire of the enemy, presenting almost a fixed mark to aim at, just as when looking at an approaching train end-on, from a station platform, it seems to be almost stationary.

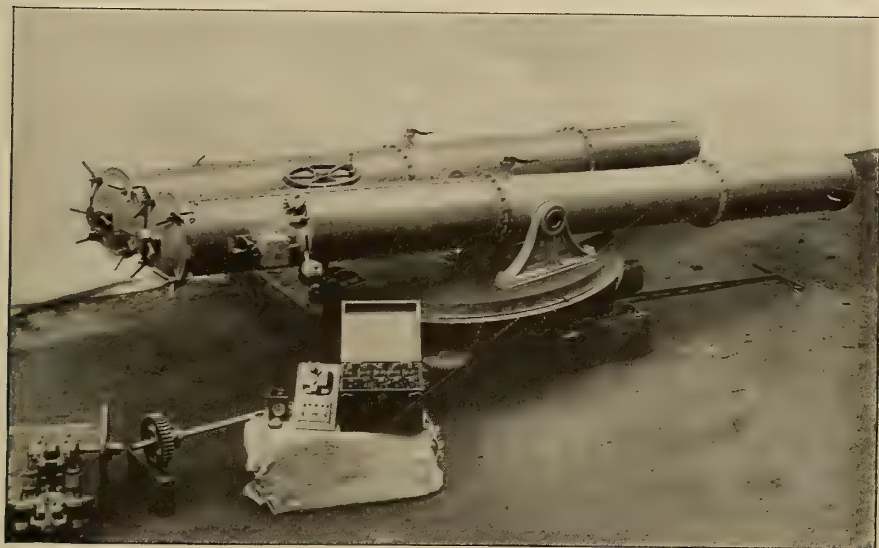


FIG. 6. A SET OF DECK TORPEDO TUBES.

The method of attack by firing the torpedoes from the side is most favoured by naval officers at the present time, as it enables the boat to rush past the enemy's ships, at the same time firing the torpedoes, thereby not presenting

so good a mark to aim at, just in the same way that the speed of a train becomes apparent when passing through a station. For this reason the bow tube is losing favour, and, indeed, is being abandoned by the British Government in all its later boats.

In the year 1880 Messrs. Yarrow & Co. constructed the *Batoum* for the Russian Government. This vessel, shown in Fig. 7, may be looked upon as the first really seagoing torpedo boat, as she steamed, unaccompanied by any large ship, from London to the Black Sea. A speed of 22 knots was obtained on her official trial. She was followed by a large number of similar seagoing torpedo boats for many naval powers.

Among others, Messrs. Yarrow built, in 1885, for the Japanese Government, a twin-screw, armoured torpedo boat, 170 feet long, by 20 feet beam, which may be looked upon as foreshadowing the present torpedo boat destroyer. She was put together in London, taken to pieces, then sent out to Japan and there riveted up, and after being in service eight or nine years made a name for herself by leading the torpedo attack at Port Arthur during the late war in the East.

Her name was the *Kotaka*. She was provided with one-inch plates around the machinery and boiler compartments, which served as a protection against all small arms. It may become an important question for naval officers to consider how far this protection is worth the increased weight and consequent reduction of speed which it involves, but there can be no doubt that the security thus obtained for the engine room and stokehold staff adds very much to their energies in securing the best result, feeling, as they must, fairly safe, as compared with vessels not having this protection. The *Kotaka* serves as one of the many evidences of the far-seeing character of the Japanese naval authorities.

Fig. 8 represents a modern first-class torpedo boat, 13c feet in length, built for the Victorian Government. She attained a speed of 22.7 knots and the general arrangement of the gun armament is clearly shown in the picture. After completion she was safely navigated to Australia.

At this time complaints were made about the vibration of vessels with quick-running engines of great power, and these objections were not confined to torpedo boats, but were also raised in respect to transatlantic steamers of large size, some of which vibrated excessively, greatly to the inconvenience of the passengers and crew. It was therefore thought a subject of sufficient importance and interest to be taken up, and it was found, contrary to general belief, that the vibration was not due to the propellers, provided the latter were well-formed and carefully balanced. The defect was entirely owing to the recip-

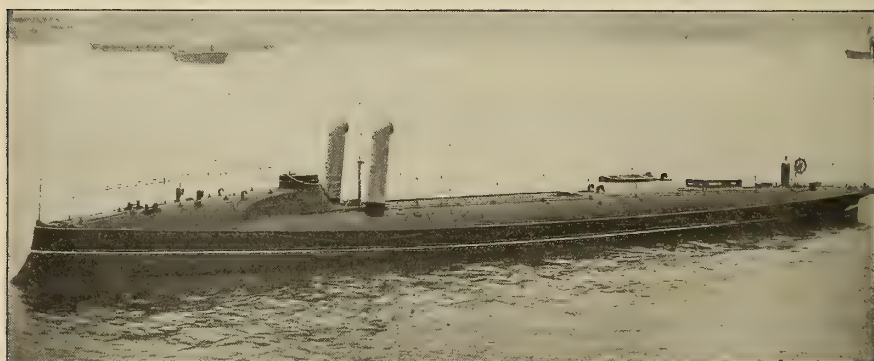


FIG. 7. THE RUSSIAN BOAT "BATOUM." THE FIRST SEAGOING TORPEDO BOAT.

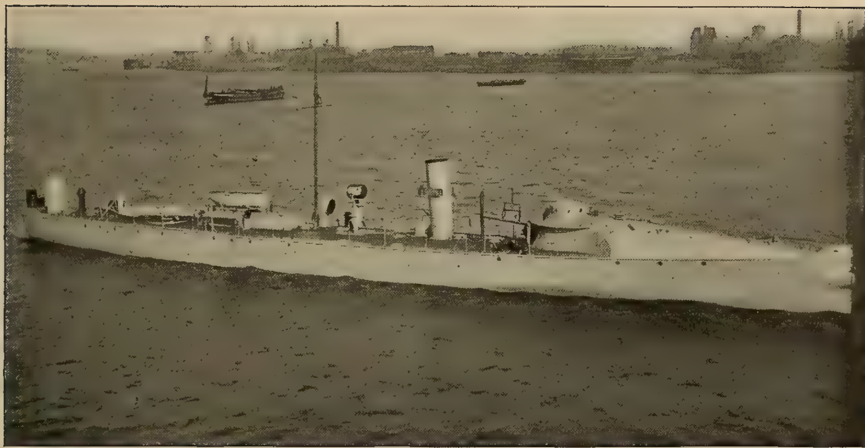


FIG. 8. FIRST-CLASS TORPEDO BOAT, BUILT FOR THE GOVERNMENT OF VICTORIA BY MESSRS. YARROW & CO., LONDON. LENGTH, 130 FEET. BEAM, 13 FEET, 6 INCHES. SPEED, 22.7 KNOTS.

rocations of the engines, which, in spite of being balanced in the manner usual at the time, set up vibrations of a very severe nature. The phenomenon did not occur at all speeds, as it was possible for a boat to be comfortable at 23 knots and almost unbearable at 17. It was also found that certain portions of the hull were subject to vibrations, and other parts were not, the vessel behaving exactly like an elastic rod, having a definite period and character of vibration.

With a view to dealing with this subject in a trustworthy manner, an apparatus was designed which Messrs. Yarrow & Co. called a "vibrometer," and an illustration of which will be found in Fig. 9. This instrument enabled an exact record to be obtained of the extent and character of the vibrations under different conditions, and it was found, whether the screw was on or off, they were the same for a given number of revolutions of the engine.

It was further shown that with a single-cylinder engine the movement in the engine room was simply vertical. With compound engines there was in the engine room both a vertical and rocking component—a kind of galloping motion, as it were. With triple-expansion engines, having all the pistons of the same weight, there was absolutely no movement of the engines at their centre of gravity, but there was a rocking movement which made itself felt throughout the vessel. The fact that the vibration was the same when the boat was at rest as when in motion made further experiments very easy to carry out, as observations could be made with-

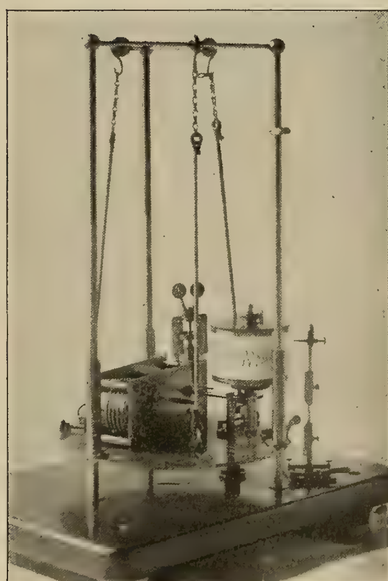


FIG. 9. A VIBROMETER.

FIG. 10. FROM A PHOTOGRAPH TAKEN WHEN THE ENGINES WERE RUNNING AT THE SPEED GIVING THE MAXIMUM AMOUNT OF VIBRATION.

FIG. 11. FROM A PHOTOGRAPH TAKEN WHEN THE MACHINERY WAS MODIFIED TO AVOID VIBRATION, THE ENGINES BEING RUN AT THE SAME SPEED AS IN THE VIEW ABOVE.

out being under way. It was found that by carefully weighing all the reciprocating parts and by assigning to each such part weights to balance it, the vibration due to that particular moving part could be neutralised.

In dealing with each such part of the engine in this way and concentrating the

resultant moving parts at two points, it was a very simple matter to fix the weight and position for two balance weights and thus blot out nearly all vibration. To make clear what is meant, consider that if a boy on a rocking horse sways his body backwards and forwards he produces a rocking movement; but if two boys were back to back on a rocking horse, and one swayed his body in one direction, while the other swayed in the opposite direction, no motion would take place.

In principle, the latter is what was done with the engines. The result of the experiments indicated the true principle to follow, and serious vibrations in torpedo boats should now be things of the past. The desired effect has been accomplished with but a very trifling increase of weight and expense. The author should here mention the work of Herr Schlick, an experimenter who has, of late, very carefully studied this subject with marked success, and who has arrived at a design of engine which secures absence of vibration, without involving any additional parts.

Fig. 10 illustrates the bow of a torpedo boat when the engines were balanced as was customary prior to the time of the above mentioned investigaton,—that is, with balance weights opposite each crank, and Fig. 11 shows the vibration when the engines were modified as described. The movements of the boat make themselves visible by the ripples on the water and a marked difference will be seen between the two illustrations.

The diagrams taken by the vibrometer are shown in Fig. 14. Fig. 12 illustrates how the vibration in the hull is felt at certain parts, there being, between the places of maximum vibration, others where there is none. The ripples made by the moving portions of the hull in contact with the water indicate this.

In connection with the hulls of these light fast boats, which vary from 3-16-inch to 1-16-inch in thickness, it has been found of the utmost importance that the design should be determined with a view to secure a uniformity of elasticity throughout the entire structure, because, if certain portions are needlessly stiff, and adjoin portions which are light, the vessel does not possess as much strength as another vessel in which the plating is uniformly light. This is a point which deserves the greatest possible attention.

The chief danger arises from the buckling of the thin plating of the hull, through strains due to waves encountered in rough weather, and in order to ensure a uniform stiffness, combined with reduction in weight, Messrs. Yarrow &

FIG. 12. A FIRST-CLASS TORPEDO BOAT SHOWING VIBRATIONS AND THEIR POSITION.

FIG. 13. A COLLISION RESULT UPON A TORPEDO BOAT GOING AT 20 KNOTS. IMMEDIATELY AFTER THE ACCIDENT THE BOAT STEAMED HOME, THE MACHINERY THROUGHOUT REMAINING IN PERFECT CONDITION.

Co. make an invariable practice of hammering all the plates into shape cold, and thus hardening them, for if the plates are bent by means of rolls or by being heated, sufficient stiffness can only be secured by increased weight. As an illustration of how much the material now available for the torpedo boat constructor will stand, the author cannot do better than refer to Figs. 13 and 15, which represent a first-class torpedo boat after having been in collision. Although the impact was a very severe one, as will be seen, the damage was quite local, and not a single joint in the machinery connections leaked, which probably would not have been the case had the vessel been built of stronger scantlings or less ductile material. The light plating formed, as it were, a gradually yielding buffer.

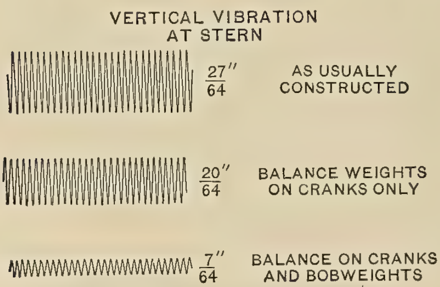


FIG. 14. VIBROMETER DIAGRAMS.

One important improvement which, of late, has been introduced in torpedo boats, is the cutting away of the dead wood at the stern, thereby securing a manœuvering power that would otherwise be scarcely possible. This system

of building was prominently brought forward by Mr. John Samuel White, of Cowes.

One of the latest of the Yarrow first-class torpedo boats is the *Viper*, built for the Austrian Government, and shown in Fig. 16. She is 147 feet long, and on a three hours' trial, when carrying a load of twenty-six tons, had a speed of 26½ knots.

There is another class of torpedo boat which is frequently employed by governments possessing large men-of-war. These are termed second-class torpedo boats and are used to form part of the equipment of large ships. In this case reduction in weight is of paramount importance, not only to secure a high speed, but also to ensure the minimum of weight when the boat is lifted by the appliance on board the parent ship. Fig. 17 represents a boat of this class, fitted with a revolving torpedo tube at the stern.

A common use made of these vessels, when fitted with machine guns, by some

FIG. 15. ANOTHER VIEW OF A BROKEN TORPEDO BOAT BOW.

FIG. 16. TORPEDO BOAT "VIPER," BUILT FOR THE AUSTRO-HUNGARIAN GOVERNMENT. SPEED, 26 6 KNOTS.

governments, is to have them act as coast guard service boats for suppressing smuggling, or to maintain lines of communication, and perform other useful work in connection with fleet operations. The present speed of these boats, with a load of two tons on board, is about 19 knots, and their dimensions are 60 feet by 9 feet.

In addition to the photograph, longitudinal and transverse sections of one of these little vessels are given in Figs. 18 and 19, showing the arrangement of the engine and boilerrooms. Attached to the stokehold bulkhead will be seen a fan, which is made to revolve with great rapidity, thus drawing the air from a cowl above and discharging it into the stokehold. The object is to produce an increased pressure of air in this hold, which is closed down, and this serves to promote the rapid combustion of the fuel under the boiler. This system is what is termed forced draft. The pressure of air is indicated by so many inches of water in a vertical column, and it may be said that the difference in pressure usually adopted between the outer air and that in the stokehold corresponds to the difference in barometric pressure at the top of a large ship's mast and that at the level of the deck.

FIG. 17. A SECOND-CLASS YARROW TORPEDO BOAT, BUILT FOR THE ARGENTINE GOVERNMENT. LENGTH, 60 FEET. BEAM, 9 FEET, 3 INCHES. SPEED, 19 KNOTS.

The forced draft system, when first introduced, was found to be a source of considerable danger to the stokers, and many lives were sacrified, for it is clearly evident that if a tube were to burst, or a sudden leakage should occur from any portion of the boiler, the stokehold would be filled with steam and the poor fellows, without sufficiently rapid means of escape, would be scalded to death.

This danger was always present at first to every mind, and, naturally, crippled the energies of the stokehold staff. For overcoming this difficulty the author's firm ultimately adopted a device

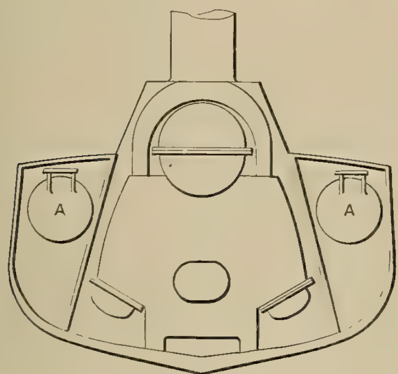


FIG. 18. CROSS SECTION OF A SECOND-CLASS TORPEDO BOAT.

which had the effect of rendering the firemen quite as safe as if they were not working under air pressure. In front of the boiler was placed a steel screen, to which were hung light hinged non-return air doors, through which the whole of the air had to pass before it reached the furnace. When working, the pressure of air in the stokehold forced open these doors, finding its way into the boiler compartment, then passing under the bars of the fire.

Now, if a tube burst in the boiler, and steam were to rush out, it is evident the pressure caused thereby would close these doors, and the steam and flame would find a vent only up the funnel. This plan had scarcely been introduced when an accident of the kind described occurred on a British torpedo boat under trial. A tube suddenly broke, the water and steam escaping with full force

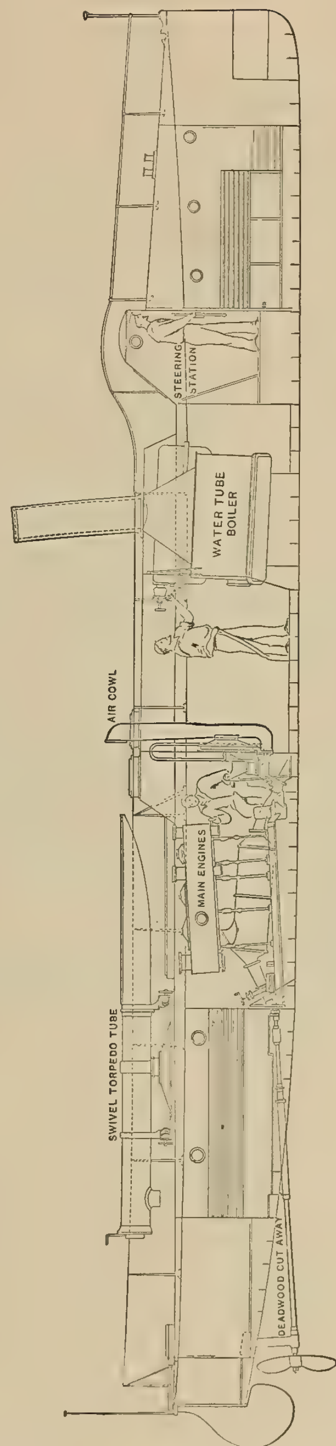


FIG. 19. LONGITUDINAL SECTION OF A SECOND-CLASS TORPEDO BOAT.

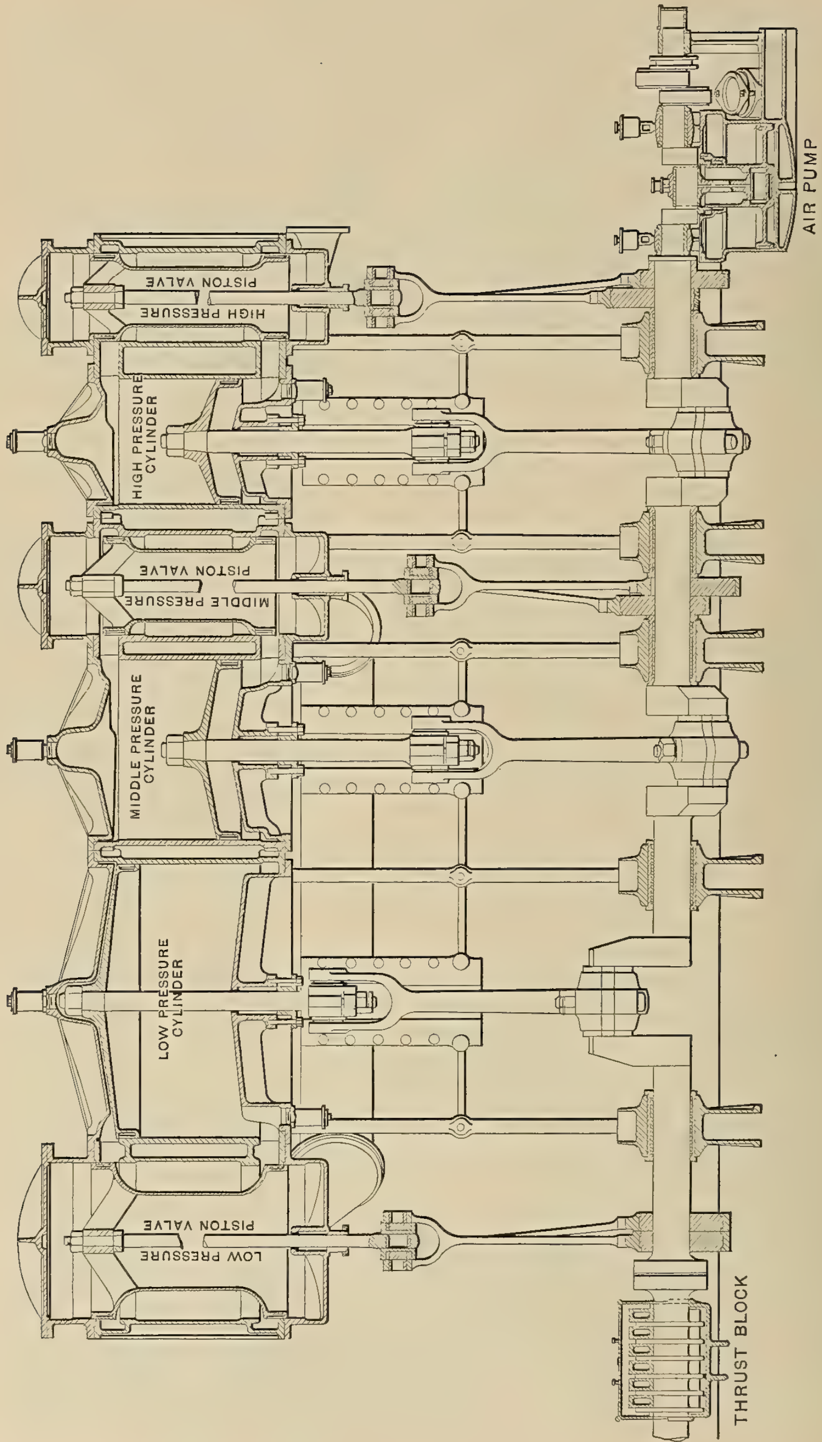


FIG. 20. A SECTION THROUGH A SET OF TORPEDO BOAT ENGINES.

through a two inch hole. As a matter of fact, the firemen knew nothing of this accident until they saw the water suddenly disappear from the gauge glasses. This incident, although it spoiled the trial, gave very valuable proof of the soundness of the system. Automatic closing air doors of different forms are now universally adopted, and, in fact, without such a device the position of the stokers in a closed stokehold is attendant with very serious risk.

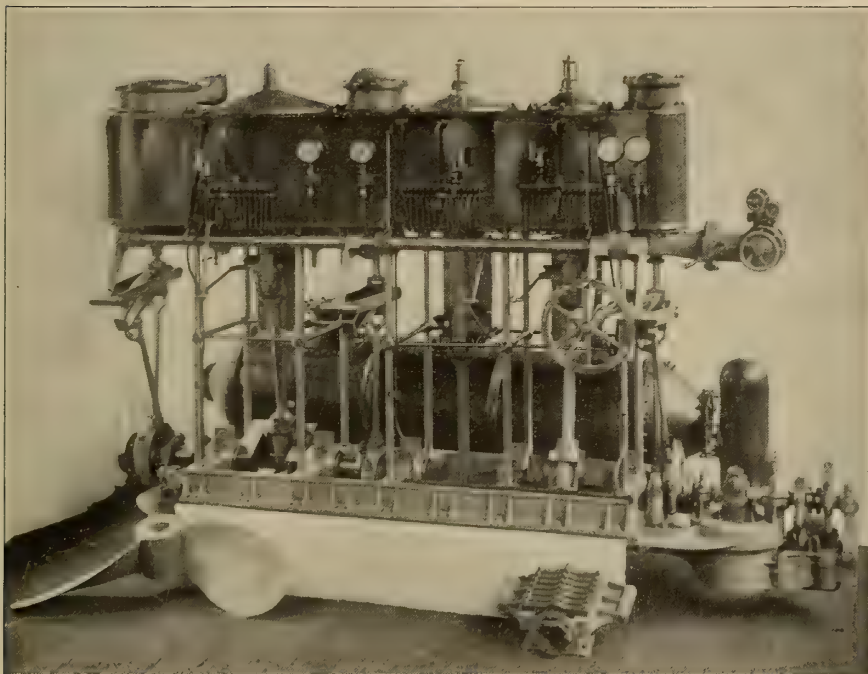


FIG. 21. A SET OF YARROW TORPEDO BOAT ENGINES.

Figs. 20 and 21 illustrate a set of torpedo boat engines, one being taken from a photograph, whilst the other is a sectional view through the cylinders. The author would here remark with reference to the piston valves, especially the low pressure one, which is of large size, that, in order to reduce its moving weight, aluminium is sometimes adopted. There can be no doubt that, in cases where lightness is of the first importance, the use of this metal is destined to greatly assist the marine engineer.

We will now deal with a class of vessel which, of late, has perhaps attracted more attention on the part of naval powers than any other. I refer to what is termed the torpedo boat destroyer, which name, though signifying a new type of vessel, represents nothing more than an enlarged torpedo boat. The introduction of these into the British navy was, no doubt, forced upon the Admiralty in consequence of the large increase in the torpedo fleets of possible rivals. The destroyer, however, offers advantages over what was generally known as the torpedo boat, inasmuch as, owing to its increased size, it carries a heavier armament, is enabled to accompany a fleet and to keep up with it in all weathers.

The *Havock*, Fig. 22, and the *Hornet*, were the first two destroyers completed for the British Government. They were

FIG. 22. THE BRITISH TORPEDO BOAT DESTROYER "HAVOCK," BUILT BY MESSRS. YARROW & CO. LENGTH, 180 FEET. BEAM, 18 FEET 6 INCHES. SPEED, WITH A LOAD OF 35 TONS, 27 KNOTS.

FIG. 23. THE TORPEDO BOAT DESTROYER "SOKOL," BUILT FOR THE RUSSIAN GOVERNMENT BY MESSRS. YARROW & CO. DURING A RUN OF 3 HOURS, WITH A LOAD OF 30 TONS, THE SPEED WAS 29.76 KNOTS.

FIG. 24. A YARROW BOILER, BUILT FOR THE DUTCH GOVERNMENT.

built by the author's firm, and the latter vessel may be considered as inaugurating the introduction of the small tube water-tube boiler in vessels of this type. The difference between the old style of tubular boiler (such as the locomotive and the return tube) and the water-tube boiler is that in the former the heated gases pass through the tubes and the water is outside, whilst in the latter the water is inside and the heated gases are outside. Boilers of this class seem now to have quite superseded former types and it should here not be forgotten that Perkins very many years ago was among the first to appreciate their advantages. He was followed in recent years by Du Temple, Thornycroft, and others.

Shortlv after the *Havock* and *Hornet*, Messrs. Yarrow & Co. built the *Sokol* for the Russian Government. This vessel is shown in Fig. 23. She is 190 feet in length by 18 feet 6 inches beam, and was the first vessel to pass through the water at a speed of over 30 knots. The Russian Government have formed so favourable an opinion of this vessel, that they are constructing a large number of exact reproductions in their own yards. As an illustration of the armament of torpedo boat destroyers, it may be mentioned that the *Sokol* has two revolving deck torpedo tubes, one 12-pounder quick-firing gun on the conning tower, and on the deck three 3-pounders.

The great importance of the reduction in weight in vessels of high speed has been pointed out, and in this respect the water tube boiler offers great advantages over all steam generators that have preceded it. As a case in point, the author may mention that Messrs. Yarrow & Co. built two vessels, iden-

tically the same, except as regards their boilers. The one had locomotive and the other, water-tube boilers. The latter boilers, including water, weighed forty-three tons, and the locomotive boilers, including water, weighed fifty-four tons, but the water-tube boiler enabled 4000 I. H. P. to be obtained, while the locomotive boiler generated steam for the development of no more than 3600 I. H. P., thus showing both an increase of 400 horse-power and saving in weight of eleven tons in favour of the water-tube design. In both cases the boilers were worked under forced draft, and, therefore, the figures may be taken as a fair comparison between the two types of steam generators.

The boilers with which the author's firm has been identified differ from others having small tubes, inasmuch as the tubes in their boilers are straight, while those of other makers are curved. No doubt this curving has been done with a view to secure elasticity, but lengthened experience has indicated that no such elasticity is necessary. In proof of this, many boilers with straight tubes can be pointed to which have been in constant use and worked hard for five or six years, and yet show not the slightest indication of failure.

Those who are familiar with the use of forced draft in combination with boilers of the old type, will learn with satisfaction that with water-tube boilers a leaky tube is quite unknown, provided the workmanship be of the best. Many of the most distinguished engineers both in Great Britain and elsewhere are of the opinion that in vessels for constant service, facility of access to the interior of the tubes is of the first importance, and straight tubes alone conform to this condition.

The present introduction, on an extensive scale, of water-tube boilers in the British navy is due to the foresight of the technical authorities at Whitehall who insisted, in the face of strong opposition, upon the adoption of this class of boiler in many of the vessels lately constructed. Fig. 24 shows a boiler of this type with the casing in place, whilst Fig. 25 gives a sectional view. In such boilers Messrs. Yarrow & Co. have obtained as much as 120 horse-power to the ton of boiler, including water and mountings. In point of fuel consumption they are slightly superior to boilers of the locomotive type. In a water-tube boiler, having tubes 1⅛ inch in diameter and 6 feet long, one horse-power is developed per tube, and there is good reason to believe that the tubes nearest the fire,

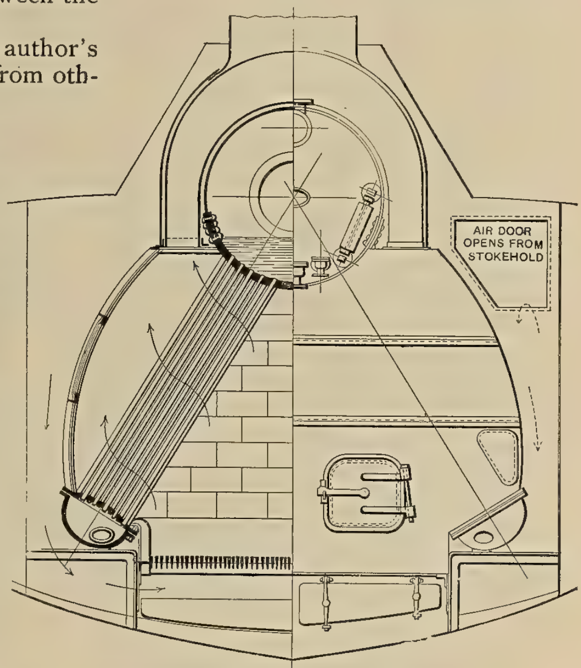


FIG. 25. CROSS SECTION OF A YARROW WATER-TUBE BOILER.

which are exposed to radiation as well as to the heated gases, develop at least three horse-power. In a set of boilers, such as are in the *Sokol*, there are 8000 tubes and their total length amounts to over six miles.

In connection with water-tube boilers it may, perhaps, be interesting to refer to Fig. 26, in which is shown the Yarrow system for expanding the tubes by electricity. The apparatus consists of a

combination of parts made in various countries, — an electric motor constructed in Austria, by Mr. Kodolitsch; a flexible Stow shaft from the United States; and an expander made by Messrs. Yarrow & Co. themselves. By this method tubes can be expanded with at least three times the rapidity formerly possible by hand. Uniformity also is secured in the quality of the work.

During the latter part of 1895 a lively controversy took place in the technical press concerning circulation in water tube boilers, and as many opinions were expressed—in some cases based upon assumptions which were incorrect—Messrs. Yarrow & Co. made a series of experiments with a view of throwing light on the laws which govern circulation. These experiments are too voluminous to be dealt with in this article, but one or two of the most striking ones may be mentioned.

FIG. 26. EXPANDING TUBES IN YARROW BOILERS BY ELECTRIC POWER.

Fig. 27 represents a glass *U* tube, the upper extremities being fixed to a chamber containing water. At the top will be seen a balance, at one end of which is a thin cord with a bob attached, this bob being immersed in one of the columns. Any circulation of water, by acting on the bob, would be indicated by the balance. It will be seen that there are three lamps on each side, adapted for heating the two tubes. In Fig. 27 the three lamps on one side are alight and circulation in this tube is naturally set up in an upward direction, drawing the water down the tube on the opposite side.

After this circulation was started, the three lamps heating the other tube, see Fig. 28 (that is the one in which the water was moving downwards), were lighted, and it was found, contrary to general opinion, that the circulation was not stopped or retarded, but actually

accelerated, as will be seen by the position of the balance in Fig. 28.

Some further trials were made with a similar apparatus, but on a larger scale,

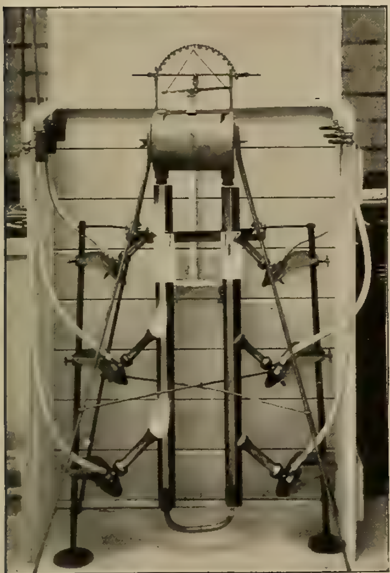


FIG. 27. BOILER CIRCULATION EXPERIMENTS WITH THREE FLAMES ON ONE SIDE.

under pressures varying from 50 to 150 pounds per square inch, and it was found that when once circulation was set up in a certain direction, all the heat might be applied to the down current without reversing the circulation, which thus remained constant. This was a result quite unexpected. It was thus proved that when once circulation is set up, it has a very strong tendency to remain constant.

In a water-tube boiler, the effect of lighting up is to first heat the tubes nearest the fire. This starts circulation, which is then maintained, although there may be no special tubes outside the boiler for bringing the currents downwards, some of the less heated tubes fulfilling this duty. These experiments also proved that the temperature of the tubes nearest the fire was, for all practical purposes, the same as that of those which were more remote from the fire. It appears that by far the greatest resistance which the heat encounters in passing from the fire to the water is in passing into the metal of the tubes and not from the tubes to the water.

There is a popular belief that water-tube boilers are more difficult to stoke than those of other forms. This, however, is quite erroneous; in fact, the reverse is the case. It is well known that, with bad stoking, boilers of the old style, especially under forced draft, can be seriously and permanently damaged, while with water-tube boilers, if properly designed, such is not the case.

In working water-tube boilers, the most efficient system of stoking differs very considerably from that which is suitable in locomotive or return tube boilers. In the latter it is of the first importance to avoid cold air passing through the fire and striking the tube plates, as it would cause excessive strains and make the tubes leak. With water-tube boilers such care is not necessary. The result is that a much thinner fire can be used with safety, and

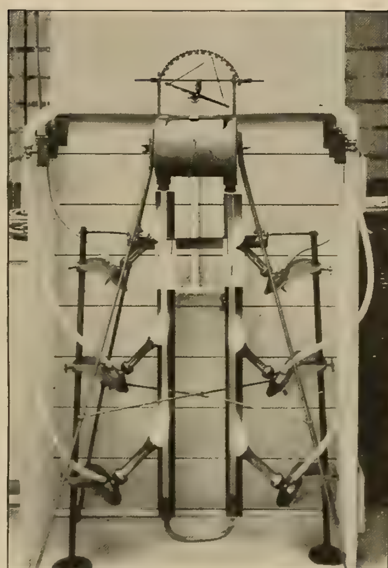


FIG. 28. CIRCULATION EXPERIMENTS WITH SIX FLAMES.

consequently the gases from the fuel can be burnt much more rapidly; for, if the fire be sufficiently thin, complete combustion can take place prior to the flame

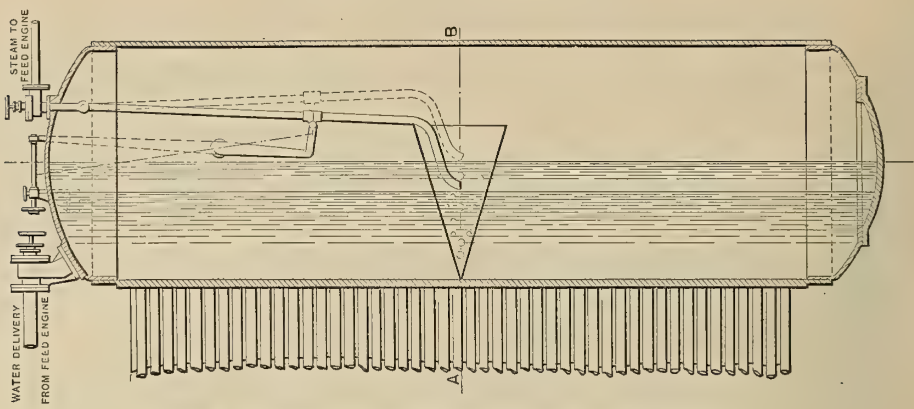


FIG. 29. YARROW'S AUTOMATIC FEED APPARATUS, SECTION C. D.

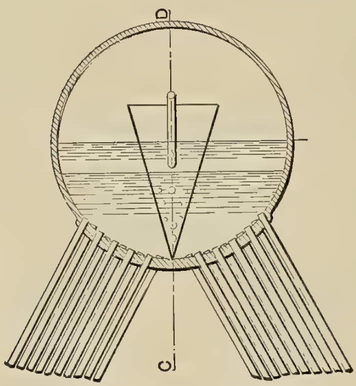


FIG. 30. SECTION ALONG A B.

coming in contact with the relatively cold tubes.

On the other hand, if the fire be thick, he length of flame is considerably extended and in many cases may be extinguished by coming in contact with the cool surfaces,—a condition which frequently results in the flame being so far lengthened as to make the uptakes and bottoms of the funnels red hot, thus even causing flame to issue and continue burning after having passed out of the funnel.

Owing to the very small area of water surface in the water-tube boiler, as compared with others, and its greater evaporative efficiency, the height of the water level fluctuates rapidly, and unless some special means are adopted for regulating this level this type of boiler does require special care in this respect. Of late, many devices have been adopted for regulating the water level by means of floats and valves. The system which Messrs. Yarrow & Co. follow is free

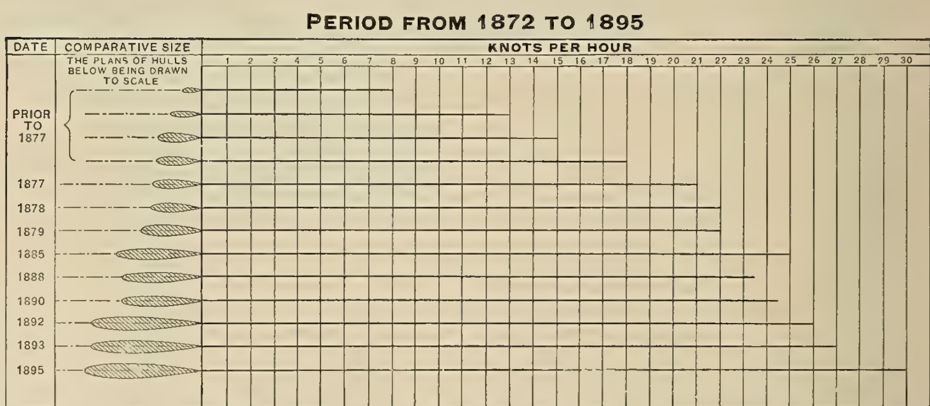


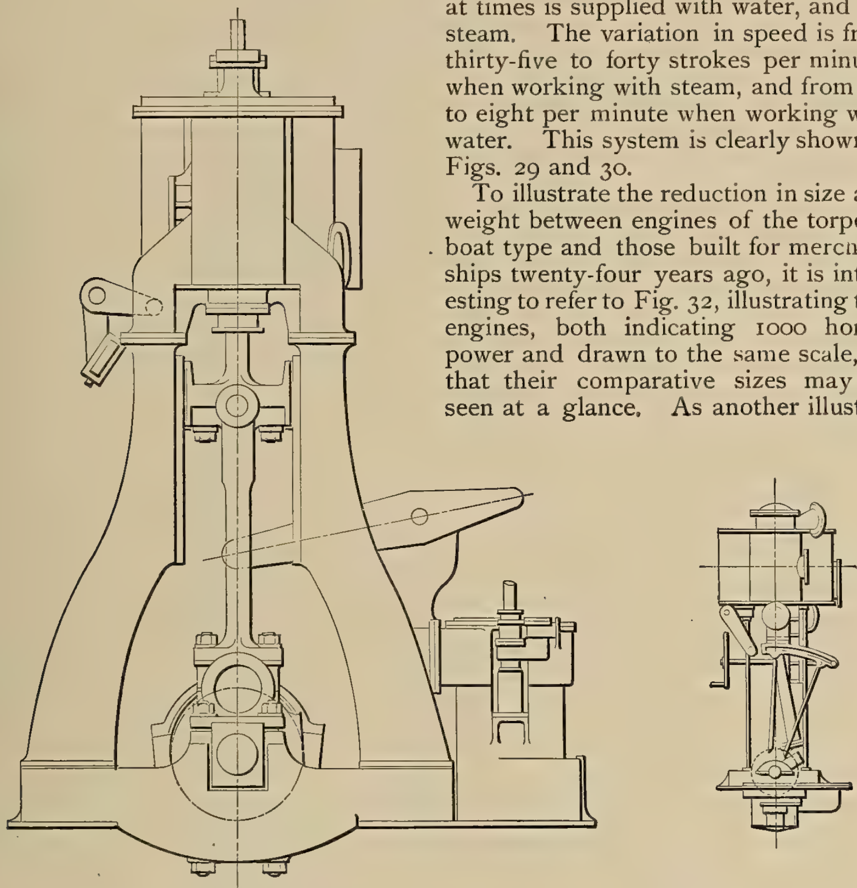
FIG. 31. DIAGRAM ILLUSTRATING THE GRADUAL INCREASE OF TORPEDO BOAT SIZE AND SPEED FROM 1872 TO 1895.

from all moving parts. The feed water is supplied to a boiler by means of a pump specially allotted to that boiler. The steam for working the pump is not taken, as usual, from the upper part of the boiler, but from near the water level. The action is as follows:—

When the water level rises, instead of steam passing into the cylinder of the feed pump, water passes into it and materially reduces the speed of the pump. When, on the other hand, the water level falls and steam finds its way into the cylinder of the feed pump, the latter starts working rapidly and continues working until the proper level is reached. There is a means of raising and lowering the pipe taking steam to the pump, so that any desired height of water can be ensured. The donkey pump never stops, although its cylinder at times is supplied with water, and not steam. The variation in speed is from thirty-five to forty strokes per minute, when working with steam, and from six to eight per minute when working with water. This system is clearly shown in Figs. 29 and 30.

To illustrate the reduction in size and weight between engines of the torpedo boat type and those built for merchant ships twenty-four years ago, it is interesting to refer to Fig. 32, illustrating two engines, both indicating 1000 horse-power and drawn to the same scale, so that their comparative sizes may be seen at a glance. As another illustration of the reduction of weight, the following may be mentioned:—The engines and boilers, with water, complete, in H. M. S. *Warrior*, built in 1860, amounted to 884 tons, and indicated 5000 horse-power. Machinery of the torpedo boat type can now be constructed to develop the same power and weigh only 110 tons.

Torpedo boats of the present day may



ENGINES OF 1,000 H. P. AS CONSTRUCTED IN 1872.

ENGINES OF 1,000 H. P. AS CONSTRUCTED IN 1896.

FIG. 32. THESE ENGINES ARE OF EQUAL POWER AND ARE DRAWN TO THE SAME SCALE.

THE ARGENTINE TORPEDO BOAT DESTROYER "SANTA FE."
LENGTH, 190 FEET. BEAM, 19½ FEET.

NELSON'S FLAG SHIP "FOUDROYANT."
LENGTH, 193 FEET. BEAM, 50 FEET.

FIG. 34. A CENTURY'S PROGRESS.

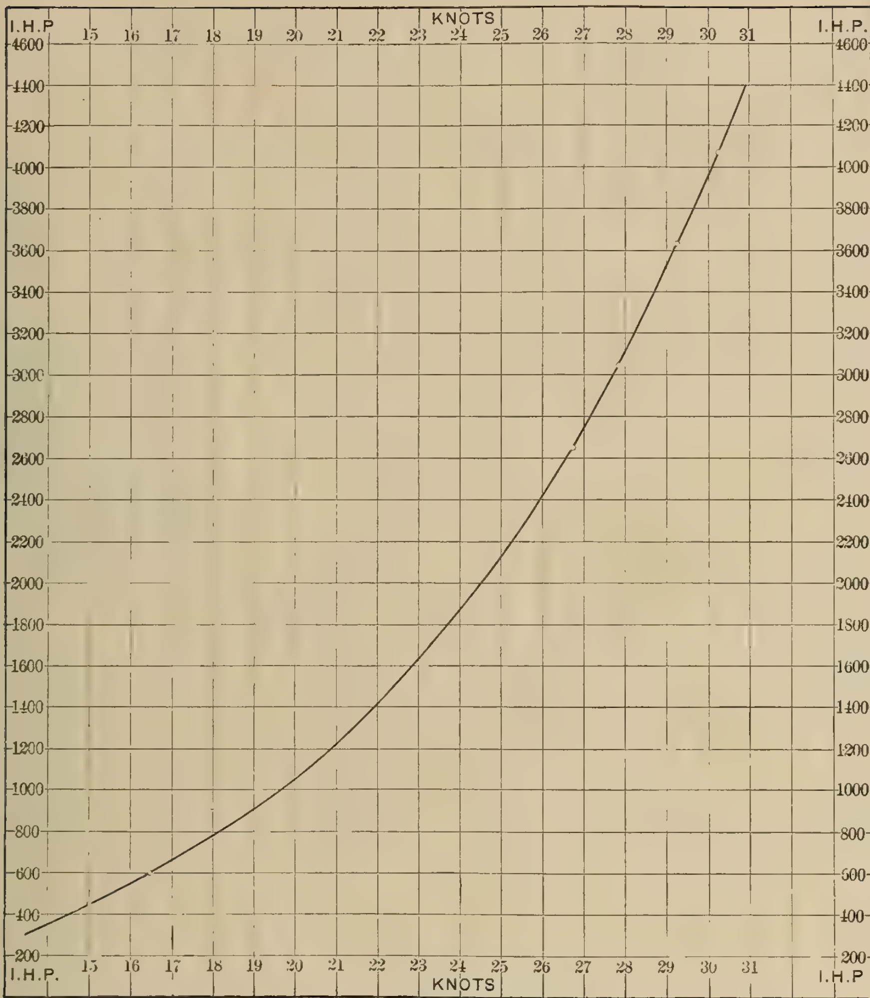


FIG. 33. DIAGRAM SHOWING POWER REQUIRED FOR VARIOUS SPEEDS OF VESSELS.

be classed roughly under the following heads:—

Second Class Boats: Speed, 18-20 knots. For coast guard service, and to be carried on board battle-ships or cruisers.

First Class Boats: Speed, 24–27 knots For coast defense and thoroughly safe in any weather.

Destroyer Class: Speed, 28–32 knots. Sea-going boats, capable of keeping company with a fleet in any weather.

The equivalent cost of the various types may be roughly stated as follows:—

One first-class torpedo boat is equivalent to 5 second-class boats.

One *Sokol* class destroyer (30 knots) is equivalent to 2 first-class boats or 10 second-class boats.

One 32-knot destroyer is equivalent to 1½ 30-knot destroyer or 3 first-class boats or 15 second-class boats.

The development of speed in torpedo boats is, no doubt, a study of special interest, and the effect of the rapid increase of speed in this class of vessel is by no means confined to it, as a basis is thus formed for the introduction of many improvements, and consequent higher speed, in vessels of large size. The reason of this is that with torpedo boats experiments can be tried of practical value, although not too costly to be prohibitive, such as could not be carried out in large vessels on account of the expense involved. The gradual increase of speed and size in torpedo boats is very clearly indicated in Fig. 31.

As indication of the range of action

of a destroyer, it may be mentioned that one of the Argentine destroyers, of the *Santa Fé* type, steamed from St. Vincent to Buenos Ayres, a distance of 4000 miles, with the fuel carried on board. It was found that the most advantageous system to follow, so as to steam the longest distance with a given quantity of fuel, was to work one engine, uncoupling the other and letting the screw revolve freely, and running at a speed of from 10 to 11 knots an hour.

To show how great is the power required to obtain higher speeds reference should be made to Fig. 33. From this curve, which is obtained from actual facts, it has been found that,—

One knot greater speed at 10 knots requires an increase of 60 I. H. P.

One knot greater speed at 20 knots requires an increase of 170 I. H. P.

One knot greater speed at 30 knots requires an increase of 430 I. H. P.

The question is often asked, What is the probable increase in speed to be in the future and in what direction are we to look for improvements with a view to obtain it? One evident mode of increasing speed is by augmenting the size of the vessel and its machinery, as if the proportion of weight allotted to the machinery is the same, a greater speed will be obtained. To secure speed by this means, however, does not involve any special skill or anything in the nature of improvements All that is necessary, is simply to reproduce the same description of hull and engines, but of a larger size.

Greater skill is shown where an exceptional speed is obtained within small dimensions, and in this respect the results obtained by M. Normand, of Havre, in his latest achievements, are specially creditable. No doubt, material of greater strength than generally adopted would admit of lighter scantlings for the hulls; probably the engines themselves may be driven at a higher number of revolutions and possibly improvements in water-tube boilers may enable a reduction of weight to be secured without loss of efficiency. Aluminium may also be introduced, as a substitute for heavier metals. It is in the saving of weight for power that advance may be looked for in the immediate future and the shipbuilder can now see his way to obtain from 32 to 34 knots.

Fig. 34 represents Nelson's old flagship, the *Foudroyant*, and the *Santa Fé*, an Argentine torpedo boat. This illustration affords a good example of the changes that have taken place within the last century in one branch of naval architecture.

THE PROBLEM OF STEAMSHIP DESIGN.

By Henry H. West, M. Inst. C. E.

TO design, and construct, a floating habitable island which shall afford wholesome living accommodation to its inhabitants, provide warehouse room for merchandise, be capable of removal from place to place at a given speed and be as safe against the perils of accident and tempest as human foresight can make it, is a problem which, if there were no experience to guide us, would probably present as great difficulties and complexities as the engineer could attack. Such is the work of the naval architect.

Like all material progress, the progress of steamship design has been gradual, and the present elaborate appliances for ocean transport, are the outcome of a slow and tentative process, in which successful experiment and the more tedious, but no less instructive, method of "trial and error," have alike contributed to the final result.

It is the object of this article to set forth, with as much freedom from technicalities as the subject will permit, some of the problems which the naval architect has to solve. To some readers the treatment of the subject will appear elementary and, perhaps, too popular; but no doubt they will forgive this when they remember that what to them may be matter of everyday familiarity, is, to many, perfectly new ground.

We have likened a steamer to a floating island. It may be well to form a clear idea of what we mean by a floating body, and what are the conditions under which it floats. When a body, such as a vessel, rests partially immersed at the surface of a fluid, unconstrained and uninfluenced by any other forces than those of gravity and the pressures of the surrounding fluid, we speak of that body as floating. In this condition the vessel's weight is manifestly a force acting vertically downwards, tending to sink it, were it not counteracted by the vertical upward pressure of the water. The fluid pressures on the submerged portion of a floating body are, at every point, normal to the body's surfaces; the directions of these pressures, therefore, may be at every conceivable angle, from vertical to horizontal. Resolving these pressures into their vertical and horizontal components, it will be seen that each of the horizontal components is balanced—cancelled—by an equal and opposite pressure, the vertical components alone remaining to support the weight of the body.

All these pressures, however, existed in the fluid before the vessel was introduced into it, and were exerted upon, and exactly balanced by the weight of the volume of water which the vessel has displaced. By this or other lines of reasoning, or by practical demonstration, we arrive at the conclusion that the volume of fluid displaced by a floating body and the body itself, must be of exactly equal weight. The weight in tons, of the displaced volume of water is technically known as the "displacement" of the vessel. If volume and not weight is meant, it is generally so stated, except where there can be no misunderstanding of the intention.

The specific gravity of salt water varies slightly in different seas, but

THE "SANTA MARIA," COLUMBUS' FLAG SHIP.

practically there are thirty-five cubic feet of sea water to one ton weight, and this is the standard upon which all calculations are based.

These are the natural facts from which the naval architect starts, and having approximately estimated the total weight of his proposed vessel, including her equipment, stores, passengers and cargo, this weight, converted into terms of cubic feet of salt water, gives him his first approximation to the volume of displacement which he must provide.

Though the immersed part of a ship is symmetrical about the middle longitudinal vertical plane, her form not being one of the regular mathematical solids, a series of measurements must be taken, and a somewhat tedious calculation made in order to ascertain its exact capacity. For preliminary purposes, however, a fair approximation may be made by assessing it as a percentage of the capacity of the circumscribing parallelopipedon. This percentage varies according to the nature of the service for which the vessel is intended, and the designer is guided by his judgment and experience, in making a suitable selection.

Such percentages are known as "block co-efficients of fineness." If the form of the midship cross section has been decided upon, a better estimate may be made by assessing the relation between the volume of displacement, and that of a prism having for its base the immersed midship cross section, and for its length the proposed length of vessel on the water line. These percentages are called "prismatic co-efficients of fineness." By such methods a fairly close approximation can be made as to what must be the direct product of the proposed vessel's length, breadth and draught of water; from this product these

principal dimensions can be resolved. But here, not infrequently, limiting conditions come into play, and one of the most common is that a given maximum draught must not be exceeded. The ocean, of course, is practically of unlimited depth, but comparatively few of the ports of the world have a sufficient depth of water to admit vessels of as great a draught as the naval architect, if he had a perfectly free hand, would desire. The extreme breadth of vessel is often limited by the narrowness of dock entrances at one or both ends of an intended voyage. The tortuous character of river navigation, or some other local consideration may put a limit upon length. Many other considerations interfere with the designer's freedom of selection, and, as will be seen later, a limitation of one dimension has, by the interdependence of dimensions on one another, an indirect effect upon all the others.

At a very early stage, therefore, there is necessity for compromise in any new design. If conditions are inconsistent with one another, one or more must give way, or the best practical compromise must be effected between them.

THE BRITISH TRAINING SHIP, "ST. VINCENT."

A STEAMER'S FRAME IN THE YARDS OF MESSRS. SWAN & HUNTER, LTD., NEWCASTLE-ON-TYNE, ENGLAND.

Of the various types of moderate-speed cargo vessels, so large a number has been built that, within somewhat narrow limits, the best practical combination of qualities for the conditions which, at present, rule this class of vessels, has been evolved. It would hardly be too much to say that, given the nature and quantity of cargo to be carried, and the amount of money to be paid, the design to be adopted is almost fixed by this statement of the requirements. But even here, there always has been, and will be, scope for the exercise of ingenuity, in arranging details so as to increase the efficiency of the vessel as a freight earning machine.

Under the pressure of modern competition, which has attacked the ship-owning community as severely as any other industry, there has been a constant and urgent demand to increase the *paying load* of cargo steamers. This demand has been responded to in several different ways. The weight of the ship herself has been reduced, and since the earliest days of iron shipbuilding great strides have been made in this direction. The scientific study of cases of structural weakness which occasionally occurred in times gone by, combined with enlightened experience and the courage which is an essential quality for the designer of any great structure, made it clear that if materials were distributed with a greater regard to true principles, lighter as well as stronger vessels might be built. It would be absurd to say that finality has even yet been reached in this respect.

Still further gains have been made by the use of steel instead of iron. The adoption of a material which is proved to be, for the same weight, nearly 50 per cent. stronger than iron, evidently gave great facilities for substantial reductions in the scantlings of the material used in construction. If the future should offer us, at a commercially practicable cost, a material of still greater tensional and compressional resistance, combined with toughness and with freedom from waste by corrosion, it is impossible to say how much further we may go in making steamers lighter than hitherto.

In the machinery department the efforts of the naval architect—and in this term must be included the marine engineer, for they have now become one and indivisible—have been addressed to the economy of weight by reducing the quantity of fuel required; and here very marked advancement has been made. This is a most important feature. The immense size of the famous *Great Eastern* was not, as many suppose, a piece of wilful determination to build a leviathan, but it was mainly due to the great weight of coal which, in her day, was needed for an Eastern voyage at her intended speed. The consumption of fuel for a given power was, at that time, more than three times what it is to-day. This fact has made it possible for freight steamers to compete advantageously with sailing vessels, on almost every voyage in the world; voyages that a comparatively few years ago could not have been contemplated for steamers at all.

By the gradual changes which have taken place from engines with cumbrous side levers, or heavy gearing, to the simpler direct-acting engines of the present time, and by the use of higher steam pressure and greater piston speeds, some economy in weight of machinery has been accomplished; this, however, has been largely masked by the addition of surface condensers, heavier boilers and an ever increasing multitude of auxiliary engines and appliances, which the increased size and complication of ships and their machinery have rendered imperative.

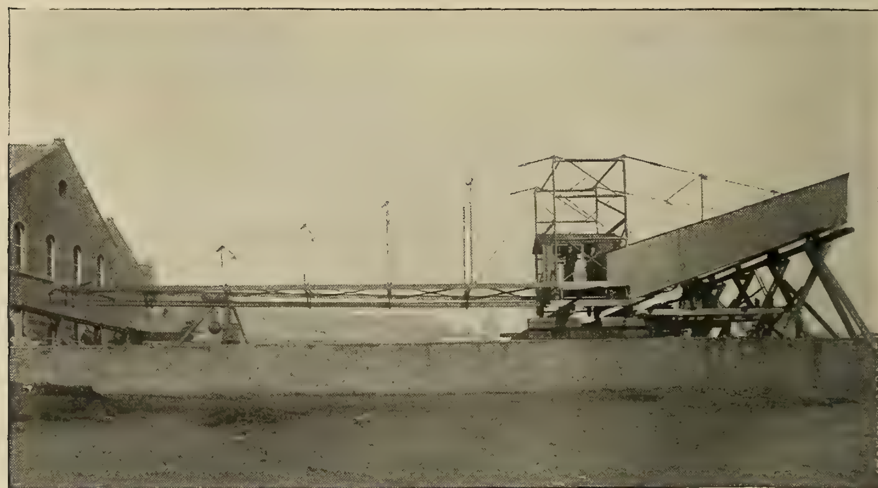
A very natural method of increasing the paying load of steamers was to immerse them deeper in the water. In the early class of cargo vessels this course led to several serious disasters. in many, if not in most, of these vessels, the necessary openings for light and air over the engines and boilers, were merely covered with slight casings and skylights, only raised a very small amount above the deck level. So long as these vessels had a good, bold freeboard above the water, and were care-

fully nursed in bad weather, all went comparatively well; but when deeper and deeper immersion of the vessel was attempted, these imperfectly protected openings were brought dangerously near the surface of the water; heavy seas broke over the decks, wrecking the skylights, swamping the machinery, and causing, only too frequently, the gravest disasters. The problem, however, of retaining the commercial advantages of carrying the heavier load, while not endangering the safety of the vessel through this element of weakness, or rather of insufficiency, was gradually solved.

It would be out of place here to give a detailed explanation of the way in which this defect was remedied; it is enough, perhaps, to say that the necessity of meeting this difficulty, led to a radical alteration of the design of cargo steamers, from which the modern freight vessels with long raised quarter decks, or partial or complete awning decks have been evolved, combining incidentally other great advantages, beyond the cure of the evil to which they were first addressed.

Where it can be shown that a steamer is carrying a less load than she might carry with safety to ship, crew and cargo, it is clearly legitimate to load her deeper, and thus to earn a larger freight at a comparatively small increase of expenditure in earning it. But the introduction in England, of a legal load line, has set bounds to what is practicable in this direction, and the increase of paying load must be looked for, and rightly so, in more strictly scientific directions, some of which have been mentioned.

At no very distant date, a typical cargo steamer was a small vessel with relatively large engines; to-day it is a large vessel with relatively small engines. Whether the largest vessel will always make the most money for her owner, is a question which he must answer for himself, and generally speaking he is very competent to do so; it turns on commercial considerations foreign to this article.



A CANTILEVER CRANE FOR SHIP WORK. BUILT BY MESSRS. THOS. BROADBENT & SONS, LTD., HUDDERSFIELD, ENGLAND.

Other things being equal, all experience shows that the biggest ship is the most economical carrier. This is partly due to a number of incidental charges not increasing in proportion to the size of the vessel. Apart from this, however, it is an undoubted scientific mechanical fact, that a big ship is relatively more

TURTLE BACK, OR PROTECTIVE DECK, OF THE U. S. CRUISER "OLYMPIA."

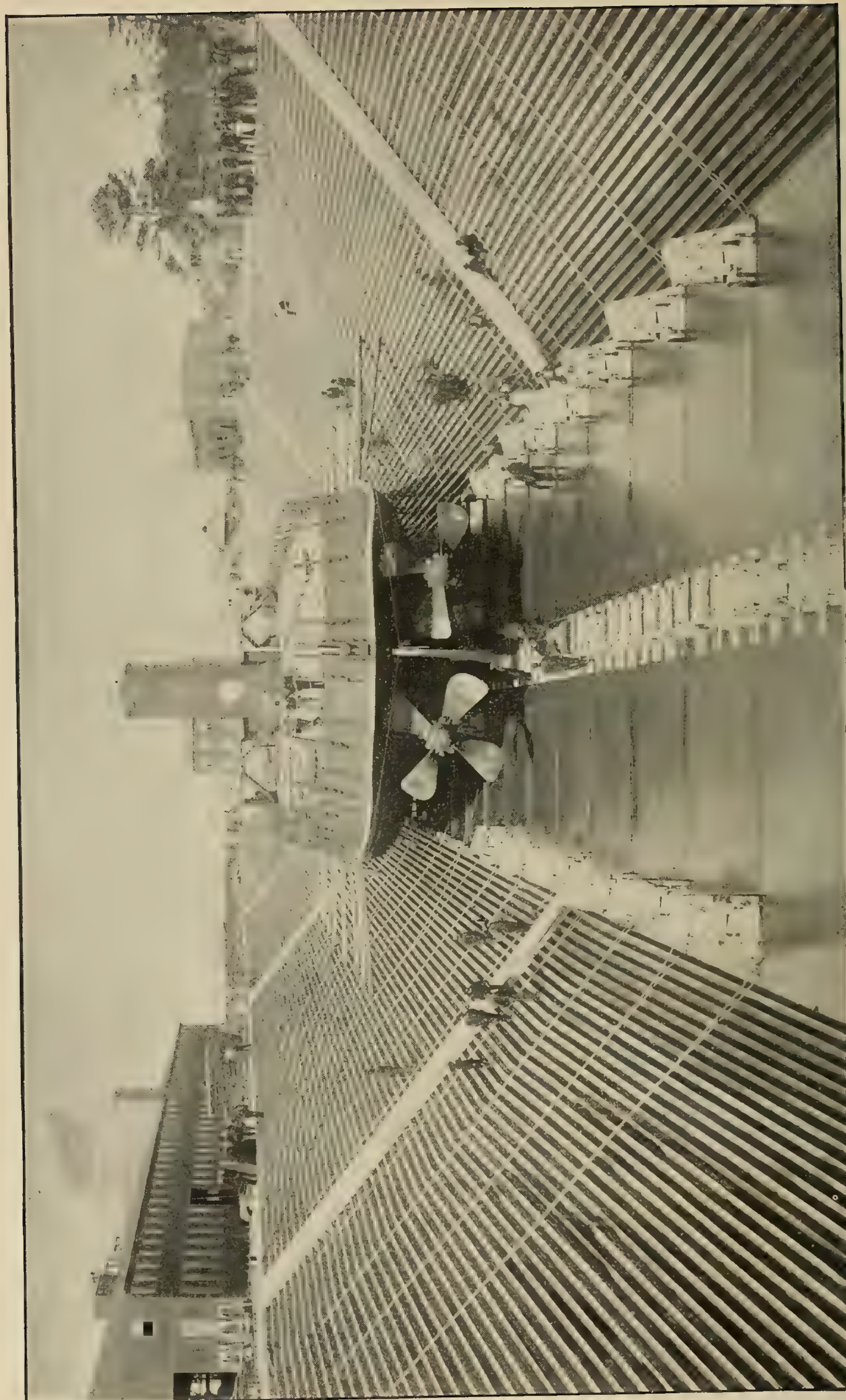
easily driven than a small one, and thus, by mere increase of size, very substantial reductions have been obtained in the ratio between fuel used and cargo carried. This has led to the multiplication of large cargo vessels, in every trade where a sufficiency of produce can be obtained to fill them. There are now in existence several vessels capable of carrying at one time, such an enormous cargo, that, if the outturn of one of them were loaded into ordinary English railway freight waggons, it would require a train of nearly five miles in length to carry one such cargo away. This illustration gives some idea of the relative facility of transport by sea and land.

The handling of such immense quantities of merchandise is a matter which requires the careful thought of the designer. He must so arrange his vessel that loading—or discharging, as the case may be—can be carried on simultaneously, at as many different points as possible, and so that every part of the vessel shall be finished loading, or discharging, as nearly as may be at the same time. A ship is only indirectly earning when in port, and with a large capital sum invested, it is important that the unprofitable time shall be reduced to a minimum.

After a voyage of two or three months' duration, during which the engines and boilers have been continuously at work, night and day, for many days together and when no artificers, beyond the ordinary engine room staff, could be employed upon the machinery, a complete examination is absolutely essential before the vessel can enter upon another similar voyage; and this necessity grows more urgent as the steamer grows in years.

The time available for this purpose is mainly the time occupied in the discharge and loading of cargo, and as this period, by continual improvements, tends to get shorter and shorter, it behooves the designer, not only to study the highest efficiency of the propelling apparatus, but also how repairs may be reduced to a minimum of cost; and, by devices for reducing the labour of examination and overhaul, to secure that it shall be accomplished in the least possible time. A designer, therefore, should be experienced in the important subject of maintenance,—a quality which he can only attain by practical contact with the subject.

Since the greater part of these repairs must be going on during the time of discharge and loading, provision has to be made for keeping up a steam supply



A DRY DOCK VIEW IN THE YARD OF THE NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY, NEWPORT NEWS, VA.

to the machinery which deals with cargo, and for other purposes on deck. A special boiler must, therefore, be arranged to meet these requirements, or the boiler power of the vessel must be subdivided into sections, one of which may be supplying steam, while the others are laid off for cleaning or repair.

A very imperfect idea of the work of the naval architect in the design of cargo steamers would be obtained, if something were not said on the subject of the strength of such vessels. A structure which is submitted to such violent and varying strains as a sea-going steamer may have to sustain, requires the most careful consideration of the structural strength. How is the nature and intensity of these strains to be estimated? If ships were constantly at rest in smooth water, an approximate estimate might be made of the strains to which the structure would be subject; but when, to these statical conditions, have to be added the strains due to the unequal and constantly varying support of a wave-distorted water surface, and those due to the dynamical effects of rolling and pitching, the constructor is brought face to face with a problem of almost hopeless complexity. Here experience, embodied in the rules and tables of the various classification societies, comes to his assistance.

From commercial considerations, such as economical conditions of insurance; the transfer of property in ships; the securing of profitable employment, and the like, it is practically imperative that cargo steamers, with few exceptions, shall hold a certificate of character from some recognised classifying body, whose impartiality and independence is guaranteed by its constitution. Amongst such bodies, Lloyd's Register of British and Foreign Shipping has, by its age and its honourable career, won for itself the highest prestige of any such society in the world. A younger, but equally honourable and competent authority, of a similar kind, has been established in the North under the title of the British Corporation for the Survey and Registry of Shipping. In most maritime countries, similar institutions are in existence.

In cases, therefore, where classification is necessary—and as we have seen, this covers a very large percentage of all the cases—a reference to the published rules of the selected society supplies the scantlings which the parts of a steamer of any given size, form and proportions, should have in order to secure the character desired. But the best shipbuilders and naval architects never lose sight of the fact that such published requirements are intended to be the *minimum* scantlings; and, notwithstanding the natural tendency of private interest to make the minimum the maximum, they test the sufficiency of the scantlings by referring them to their own experience, enlarging that experience where it is not in itself sufficient, by extending it in the light of first principles.

The intensity of longitudinal sea strains, that is, of such sea strains as tend to bend a vessel, when viewed as a girder, manifestly increases, other things being equal, when the ratio of length to depth and to breadth is increased. Unless, therefore, the designer is prepared to face the increase of weight necessary to provide compensation for excessive proportions, a reasonable relation between length and depth and breadth, must be maintained, the effect of which is practically to limit the choice of dimensions.

When the scantlings of the material of construction have been decided upon, a very close approximation may be made to the weight of the intended vessel, the estimate being based in part upon experience of other ships, and in part upon calculations which are addressed to the effect of special features of the new design.

Before dimensions can be finally determined, their relation to stability in connection with other elements of the design must receive careful consideration. It is not necessary here to discuss the theory of the stability of ships, but it may be well to point out some of the conditions of stability. If we revert to the remarks made in the earlier part

of this article, when referring to the displacement of floating bodies, it will be remembered that the weight of the vessel was spoken of as a force acting vertically downwards, opposed and balanced by the vertical upward pressure of the surrounding water. The resultant line of action of the vessel's weight is the vertical passing through her centre of gravity; the resultant of the vertical upward pressure of the water is the vertical passing through the point which was the centre of gravity of the displaced fluid, technically known as the "centre of buoyancy."

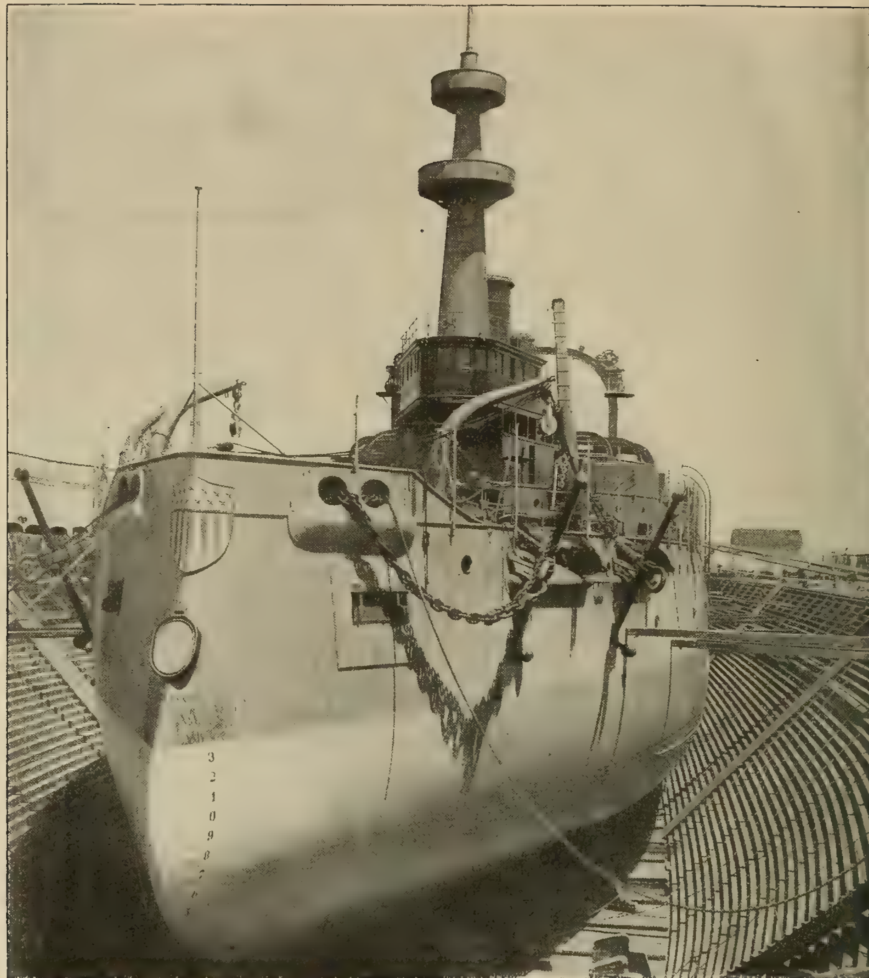
For a vessel to float freely and at rest in still water, it is clearly necessary that these two points, her centre of gravity and centre of buoyancy, shall lie in the same vertical, for otherwise the two forces of weight and buoyancy would form a "couple" tending to turn the vessel about some axis until a position of equilibrium was attained. The only possible positions of equilibrium are when these two points are in the same vertical line.

The equilibrium may be stable, unstable or indifferent, depending on conditions which we need not discuss; suffice it to say, that it is the business of the naval architect so to design his vessel that when an external force comes into play tending to incline the ship from the upright, the effect of that force shall be to establish a couple between the vessel's weight and the force of buoyancy, the tendency of which shall be to counteract the inclining force; in short, that the inclining force shall bring into action a righting force, sufficient to prevent an undue inclination.

TORPEDO BOAT DESTROYERS ON THE STOCKS IN THE YARD OF PALMERS SHIPBUILDING AND IRON CO., LTD., JARROW-ON-TYNE.

It might be supposed that this righting force could hardly be made too great, and that if it was sufficient the designer need not trouble himself about its being too much. But this is not so. If this force is allowed to be

THE AMERICAN LINE STEAMER "NEW YORK" IN THE DRY DOCK AT THE YARD OF THE NEWPORT NEWS SHIPBUILDING AND DRY DOCK CO.



THE U. S. BATTLESHIP "OREGON" IN THE DRY DOCK. BUILT BY THE UNION IRON WORKS, SAN FRANCISCO.

too great, or as it is called, if the vessel be too stiff, very grave racking strains are brought to bear on the ship's structure, and the comfort of those on board is seriously interfered with. In passenger ships especially, this is a matter of very considerable importance. The relation to one another of the dimensions of breadth and depth, as well as the vessel's form, have an important influence on this point. Limitations which special circumstances may place upon one dimension, have thus, in another way, a very practical, if not a very direct, effect upon the other dimensions. In merchant vessels, and indeed in any vessel where the unloaded condition of the ship differs widely from her loaded condition, the naval architect has only a very limited control over the height of the centre of gravity in the sea-going condition,—a matter of the greatest importance in relation to stability. He can, therefore, only provide that under certain conditions of loading (which should include the most unfavourable circumstances likely to occur), the centre of gravity shall be sufficiently low for safety.

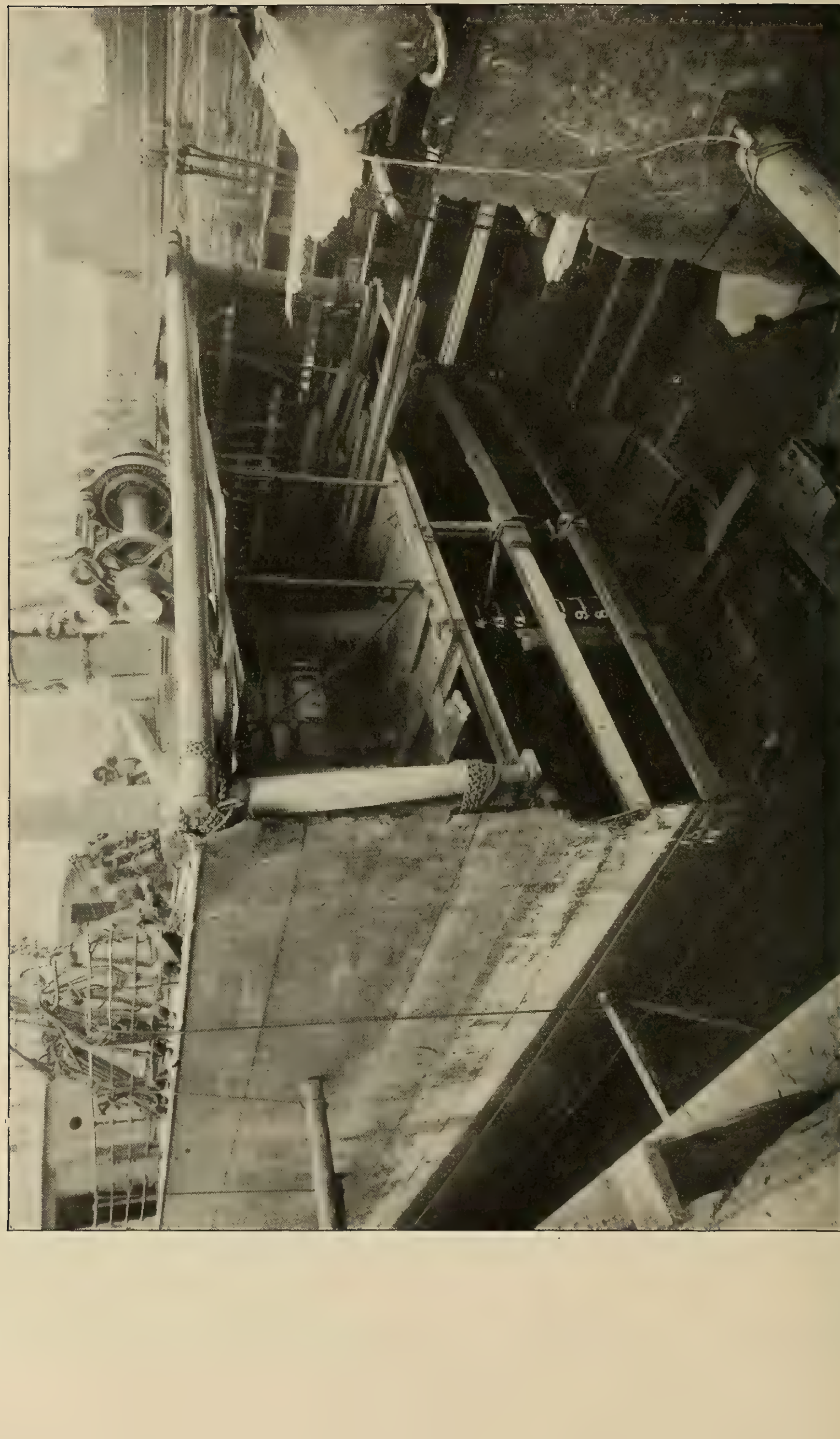
Exact calculations of stability cannot

be made until the vessel's form is finally and accurately determined, but, by comparison with the known qualities of similar vessels, a first approximation to the stability, so far as it is due to form and proportions, may be made with sufficient accuracy for preliminary purposes. Similarly, experience will enable the designer to make a fairly accurate estimate of the position of the centre of gravity of the finished and equipped vessel, which, being afterwards tested experimentally, supplies useful data for future use.

In the ordinary course of business, most steamers have, at some time or another, to move from the port of discharge to some other port to receive a new cargo. A ship may be perfectly stable and safe in her loaded condition, and yet not sufficiently stable to go to sea in her light condition; or, if stable enough, she may be too light in the water to be efficiently propelled, or to behave well in a seaway. To put ballast into the holds is costly; the ballast must be bought; the cost of handling, in and out, is considerable, and, what is probably of greater importance, time is lost in the process.

To meet this difficulty water ballast has been introduced, carried in tanks forming a double bottom to the ship. By the simple means of opening valves in communication with the outside water, these tanks can be filled from the dock either after the cargo is discharged, or, if necessary, while that process is

A TRAVELLING CRANE IN THE NEWPORT NEWS YARD.



STEAMER BROKEN IN TWO AS THE RESULT OF COLLISION AND SUBSEQUENT BEACHING, FLOATED INTO THE REPAIR DOCK OF MESSRS. CLOVER, CLAYTON & CO., LIVERPOOL.

going on. On arrival at the loading port the steam pumps are set to work and the water is pumped out; in the meantime a new cargo may be coming on board. This system has the incidental advantage of giving the vessel an inner skin, which has often proved of immense advantage in cases of stranding.

The speed of cargo steamers does not usually present any serious difficulties. The immense number of such vessels in existence, of almost every size and type, affords ample data of the most practical character, to which appeal can be made, if necessary; and the speed being generally moderate, the possible range of power required for small variations, either in speed or displacement, is comparatively unimportant. In the same way, the comparatively small number of people who have to be provided for, and their simpler mode of life, make the domestic side of such designs almost a matter of mere routine.

The confidence which experience has shown, may be justly placed in modern steamship machinery, has made sail power for steamers a matter of very little importance. Sail is carried, but only to a small extent; and, as the principal use of the masts is to serve as derrick posts for the loading and discharge of cargo, their number and position is made subservient to this purpose, rather than to any efficiency of propulsion.

The volume and velocity of the column of water thrown aft by the propellers of screw steamers is so considerable, that the rudders of large vessels of this kind cannot be turned to any considerable angle, when under weigh, by any ordinary appliances worked by manual power, and much ingenuity has been expended in devising steam and hydraulic steering engines. These have proved so successful, and so economical of hand labour, that there are now but few steamers which are not fitted with them.

The appliances for securing a steamer at her anchorage, technically known as "ground tackle," were long of such a character as fully to maintain the reputation of sailors for strong conservative instincts, but in these latter days, innovation has stormed even this last citadel.

From what has been said it will be seen that in the design of even a mere cargo steamer, complex problems have to be attacked; problems of which the solution involves sound judgment, prudence and foresight in order to effect a just compromise between conflicting conditions, and that the result may attain that commercial success without which no industry can prosper.

It is, however, when some new departure has to be taken, that the greatest skill of the naval architect is manifested. When exceptional lightness of draught is demanded, or unprecedented speed must be achieved; when luxurious accommodation has to be provided for passengers or a combination of all these requirements calls for their embodiment in a concrete design; it is then that the designer's ingenuity must be most active, and his art and science be brought to bear on the problem before him, untrammelled by any servile adhesion to precedent, and yet guided to success and safety by a mature experience. Many of the problems which arise in the course of the naval architect's work are common to vessels of every class, varying only in their special adaptation to particular purposes.

With the exception of ships of war there is probably no type of vessel which excites so keen an interest in the public mind as the modern high-speed Atlantic passenger steamer, so aptly christened "the greyhounds of the Atlantic." Nor is this interest to be wondered at, when we bear in mind the influence these vessels have had upon the commercial and social relationships of two continents.

Called into existence by the mighty stream of traffic, which constantly ebbs and flows between Europe and America, they have been improved by the effects of the keenest competition, until, from the passengers' point of view, the latest examples appear to be as nearly perfect as human skill can make them. Com-

bining a speed of transit which practically annihilates distance at the rate of nearly 600 statute miles a day, with the luxurious appointments of a first-class hotel, these sea palaces seem to leave little to be desired. But the enormous cost of working one of these steamers across the Atlantic, suggests that, from the commercial standpoint, there is still scope for great improvement; and we cannot doubt that, in the future, the most perfect of these splendid specimens of naval architecture will be surpassed.

Unlike the cargo steamer, probably the most serious difficulty which passenger vessels present to the designer, is that of speed. Put broadly, the power required increases in the ratio of the cube of the speed. In other words, double the speed means eight times the power, and, in some cases, even more. It will, at once, be recognised that, at the high speeds of Atlantic passenger steamers, the question of power assumes most formidable proportions. Power involves weight, not only of the machinery, but also of the fuel which must be carried. These, in their turn, affect the displacement, and the displacement again, affects the speed. But by assuming a margin of power, which in its effect on the speed, will exceed the effect of the extra displacement which it involves, this Gordian knot may be cut.

To borrow a simile from a popular writer, hardly known to this generation, a ship is a sea plough, ploughing a furrow of the size and form of her immersed midship section, and of a length equal to the distance she has traveled. The stem is the coulter, and the gently curved sides of the bow are the mould-board, formed so as to turn aside gradually, and with as little shock as possible, the disturbed water furrow; but, unlike the land plough which leaves its furrow dead and quiescent, heaped up on the land, the sea plough must allow the disturbed water to fall back again into its old position as gently as it was first disturbed.

The sea plough must, therefore, have a mould-board at the tail, requiring at least as much care in the design of its form, as the mould-board at the fore end. Mobile as water appears to be, it has weight and viscosity, so that its cleavage, the turning of it aside and heaping it up into waves, the frictional adhesion of the film of water next to the sides and bottom of the vessel, and the creation and maintenance of eddies and currents by the forcible tearing away of particle from particle cause resistances which are vastly increased at high speeds, and demand the exertion of powers such as are rarely developed in any other form of motor.

The late Dr. Kirk devised an ingenious method by which, with the aid of a simple piece of arithmetic, a preliminary estimate could be formed of the mean angles of entrance and run, and of the extent of surface subjected to water friction, before the ship's lines were designed, thus greatly facilitating the first approximation to the power necessary for a given speed.

These preliminaries of speed, weight, power, fineness of form, dimensions (actual and relative) having been approximately decided, the real work of designing begins. No amount of investigation has yet revealed to us a form of least resistance, and when the conditions to be fulfilled have once been established, the design of the vessel's form is not so much dependent upon formulated theories, as upon that intuitive sense of beauty and fitness, which is characteristic of the artist rather than of the mathematician.

The delineation of such a form as that of a ship by a series of horizontal, transverse, longitudinal, and even diagonal sections, bounded on one or more sides by the trace of the curved surface of the ship, all of which curves must not only be fair and continuous in themselves, but absolutely consistent with all other curves in which the same point occurs, and at the same time enclose a volume of a certain specified amount, is an art which can be attained only by native talent and patient and conscientious labour.

The lines being laid down, exact calculations of the qualities of the proposed vessel are made and any necessary cor-

PLACING A 13-INCH GUN IN THE AFTER TURRET OF THE U. S. BATTLESHIP "OREGON" AT THE UNION IRON WORKS, SAN FRANCISCO, CAL.

rections introduced. The laws, however, which govern the speeds of steamers are as yet only imperfectly understood; and there is still some element of uncertainty which can only be solved by experiment, and for which some margin must necessarily be allowed. Experiment on a scale which could be deemed to represent, satisfactorily, the conditions existing in a real ship, would appear to be utterly out of reach at any reasonable cost; but amongst the many inestimable services which the late Mr. William Froude rendered to the scientific naval architect, perhaps none has been of greater value than his investigation and formulating of the laws which correlate the resistances of a model with those of a full sized vessel of the same form, driven at a corresponding speed.

Mr. Froude's experimental apparatus consisted of a tank, of sufficient length

for his models to attain a sufficient and uniform speed, and of exquisitely devised apparatus for obtaining automatic records of speeds and resistances from models accurately representing the full sized ships. Having established a just law of comparison, he was able to predicate, from experiment, the power required with a given form of vessel for a given speed, and his investigations have been of the greatest service to the designers at the British Admiralty.

The construction and equipment of an experimental tank, and the maintenance of the necessary scientific staff, are beyond the reach of most private concerns, and there is only one commercial shipbuilding establishment in England, that of Messrs. William Denny & Bros., at Dumbarton, which is thus equipped. But the promulgation of the laws and formulæ on the subject, first put into a practical and available form by Mr. Froude, has enabled naval architects rightly to apply the known results of existing vessels to projected vessels of the same form but of different dimensions. It is not too much to say, that without the knowledge which Mr. Froude's labours have given to the world, the marvellous results attained by ocean steamers in this *fin de siècle* would have been still a thing of the future.

Calculations must be made to ascertain what the trim of the vessel will be in her sea-going condition; that is to say, how she will sit in the water, whether the line of the keel will be level, or more deeply immersed at one end than at the other. It is usual for the after end to be deeper in the water than the fore end by a small fraction of the maximum draught, and this deeper immersion aft is technically known as "trim by the stern." It is expressed in feet and inches which state the difference of draught at the stem and at the stern post. Thus, trimming one foot six inches by the stern, means that the draught aft is eighteen inches more than the draught forward.

The position of important weights, such as the machinery and boilers and the store of fuel, must be so disposed that, when all weights, inclusive of stores and cargo, are on board, the vessel will be in the intended condition as to trim; and, since the fuel is a varying quantity during the voyage, it must be so placed that its consumption will not put the vessel seriously out of trim.

When the vessel's form has been finally decided and her lines accurately drawn down, and the space to be devoted to the propelling power and its supply of fuel determined, both in amount and position, the greatest ingenuity must be exercised to make the most of the space devoted to the accommodation of the ship's company and her passengers. The necessity for light, which can only be obtained, either from skylights above, or through the vessel's sides above water, limits the part of the ship which can be effectively used for passengers to the 'tween deck spaces at, and above, the water line. A hasty review of some of the more important requirements which modern travelers demand, will show that the designer cannot afford to waste a single foot of space.

First-class passengers must have a large and handsome dining saloon; indeed the commissariat department could not be managed at all if it were not dealt with *en bloc*. The ladies must have a drawing and music room. The studious must have a library. The men must have a smoke room. Everybody must have a bed; and all must have room for exercise in the open air, when inclined for it. Similar, but less elaborate conveniences, must be provided for those who wish to travel in the same ship, but who are unable, or unwilling to pay the highest fare. In many cases, a third class of accommodation is given for emigrants, and those to whom cost is a matter of the first moment. According to their several ranks, all these passengers must be waited upon, so that a large body of stewards and servants must be carried in addition to the crew of navigators and engineers.

With this large number of people to be fed, cooking arrangements of the most elaborate and complete kind must

THE AMERICAN LINE STEAMER "ST. LOUIS" JUST BEFORE LAUNCHING AT THE YARD OF THE WILLIAM CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHIA.

be made. Provisions must be stored in such a manner as to remain fresh and good throughout the voyage, and for this purpose steam refrigerating machinery and cold storage chambers are usually provided at the expense of some of the cargo space. A practically unlimited supply of fresh water must be allowed to everybody on board, and yet the arrangements for its supply must be such that anything like waste shall be prevented. Perfect order and system are so essential for the comfort of the community that a place must be provided for everything, in order that everything may be in its place.

The most careful watching does not entirely obviate the dangers of collision in the darkness of night, of the still worse obscurity of fog, for immunity does not depend only on the care, coolness and sound judgment of the officers of one ship, but also on these qualities being exhibited by the officers on every vessel which she may approach. Though these dangers cannot be entirely obviated, they may be, and are in the highest class of steamships, reduced to a minimum by the subdivision of the vessel into such a number of separate watertight compartments, that any one may be filled without causing the ship to founder.

This subdivision may be carried further, and be so arranged that even if the steamer were struck on a partition, thus filling two adjacent compartments, she would still remain afloat. For this to be efficiently done, the ship must not only have a high side out of water, and a consequently large reserve of buoyancy, but the capacity of each compartment must be so regulated with reference to its position, that the filling of one or two compartments shall not have a fatal effect on the vessel's trim.

For practical convenience in working, the several compartments must be in, more or less, free communication with one another; this involves doors in the partitions, or bulkheads as they are technically called, which can be readily closed watertight in any sudden emergency. Since, however, these doors are liable to be closed without notice, it is imperative that there shall be means of access to, and egress from, each compartment from the deck.

It must be admitted that watertight doors have in several cases proved unreliable in an emergency. Attempts have been made to work them automatically, but elaborate arrangements of this kind are very apt to fail at a critical moment. On the other hand, where their regulation depends on human agency, their being efficiently closed in a moment of danger and panic is, at the best, doubtful. Doors might be made in pairs with an intervening space, and arranged so that one could not be opened until the other was shut, thus maintaining the water tightness of the bulkhead at all times. It is, however,

A TORPEDO BOAT DESTROYER READY FOR LAUNCHING IN THE YARD OF PALMERS SHIPBUILDING AND IRON COMPANY, LTD., JARROW-ON-TYNE, ENGLAND.

difficult to conceive of a method of doing this which could be tolerated in any situation where a constant traffic is going on through the opening.

Probably the only absolutely safe way is to construct the bulkheads without any passage through them at all, and thus compel all traffic from compartment to compartment to go up on deck. Those who have been much concerned with the design and working of large passenger vessels, will readily appreciate the almost insuperable difficulty of doing this. Some amount of risk is inevitable, even as it is in the most ordinary affairs of life, and it is quite an open question whether ordinary doors, with all their faults, do not effect the best compromise.

In the possible event then, of the ship having to be abandoned, the designer must give his attention to the appliances for saving life. Innumerable schemes have been devised for getting out boats at sea, and the naval architect cannot be considered to have finished his work without selecting from those which experience has proved to be serviceable, the one which is best adapted to the special features of his own case.

Next to the terrible disaster of capsizing, in face of which all a seaman's resource is unavailing, the sailor has no more frightful enemy than fire at sea. Though, fortunately, this terrible accident is now comparatively rare in passenger ships, nothing must be left undone by the naval architect which foresight can provide for preventing and extinguishing fire.

Apart from questions of safety, which are ever uppermost in the designer's mind, he must invent all those little devices which anticipate, and provide for

IN A GRAVING DOCK AT PALMERS.

the passenger's wants. The passenger is by nature a grumbler, and being shut up, for days together, on an island from which there is no escape, with little occupation but to find fault, he must be an angel indeed if he uttered no complaint. It is the constructor's province, if possible, to shut his mouth by anticipation.

This huge floating caravansary has to be lighted, warmed and ventilated. The progress in lighting by incandescent electric lamps, without vitiating the atmosphere, has been an immense advantage to passenger steamers, even though it be a costly light.

The maintenance of an equable temperature, with pure fresh air free from draughts, warm enough in cold climates and cool enough in hot latitudes, presents almost insurmountable difficulties. Where spaces are so contracted, and nooks and corners so numerous, the air must lie quiescent unless disturbed by currents too violent to be admissible; and it is to be feared that even in the best vessels there must still be a smell of the ship, shippy. In recent practice all unnecessary linings have been removed, and all apartments thrown as open for the free ingress and egress of air, as is consistent with necessary privacy—a quality, by the way, which passengers would do well to remember is never absolute on board ship.

This article would extend to more undue limits than it has already reached if the various problems which the marine engineer has to solve were submitted to review. Though recent developments have worked great changes in what we may call the manufacture of power, coal as fuel, and steam as a means of using the heat evolved by its consumption, still reign supreme on ship board, and there does not seem any immediate prospect of any important change from this state of things. But, although marine practice may have long lagged behind what locomotive engineers were doing, it has now advanced by leaps and bounds, and is at least abreast of railway practice, both in respect of steam pressure and of piston speed. Artificial draught which was the making of the locomotive boiler as a rapid steam generator in a small compass, is rapidly establishing itself in steamers, with practical advantages of both a technical and commercial character.

A wonderfully light type of machinery has been adopted in the most recent torpedo boats, even for the development of very considerable powers. The conditions for large passenger steamers do not admit of similar machinery being used; but the wide margin between the three to five hundredweights of machinery, boilers and water per indicated horse-power of the average passenger steamer, and the thirty-five to seventy pounds of the torpedo boat, suggests that there is scope for some great revolution in the mechanical appliances of the vessels we are now considering. It would be vain to attempt to prophesy what direction the next great change will take, but, that change will come, is as certain as that it has come in the past.

Though this article has unavoidably drawn out to an undue length, it has only touched lightly upon a few of the salient points which press themselves on the designer's attention. This is partly due to the fault of the writer; but it is also due, in part, to the wide ramifications of the subject. If this article succeeds in creating any interest in naval architecture as an art and a science, or excites any sympathy with the naval architect in the difficulties which beset this profession, the writer has his reward.

THE LAUNCHING OF A SHIP.

By Robert Caird, F. R. S. E.

THERE is no event in the course of construction of a ship which appeals more forcibly to the imagination than the launch. There is something mysterious, something hidden, in the operation of the forces which bring it about. The mass moved is so enormous, and its motion is so dignified and apparently irresistible, that the attraction of a launch for the public is easily enough accounted for even without the more sentimental features of the beauty of the scene and the poetical suggestiveness of the vessel's first introduction to her native element.

In honour of the occasion flags are profusely displayed, and they serve the additional and prudent purpose of warning passing craft; but they also draw the crowd. In the words of the paraphrase,—

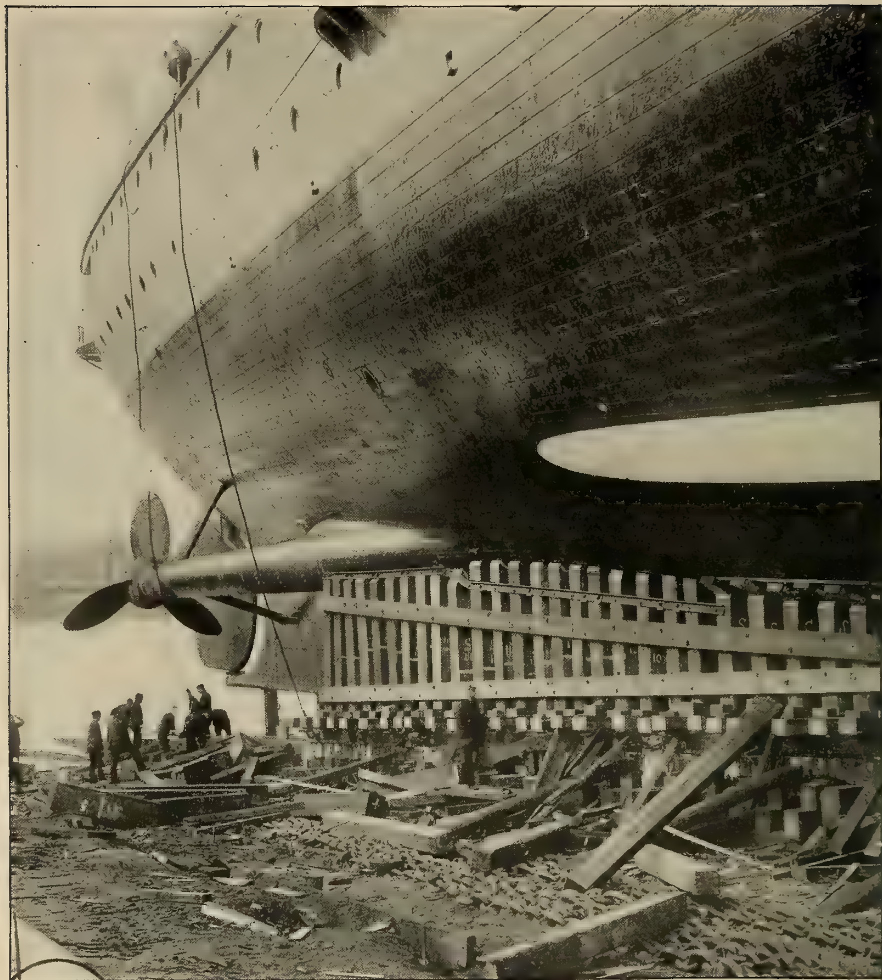
> "The rush may rise where waters flow
> And flags beside the stream."

The day of an important launch is practically a holiday in a ship yard, and it is impossible, or nearly so, to check the inrush of sightseers. A large crowd, besides the inconvenience of it in hampering the necessary operations, is a nuisance in that it adds to the general excitement and is apt to unsettle the nerves of the foremen and others in charge. The risk of accident to incautious and foolhardy spectators is an additional weight of responsibility, a care the more to the manager, at a time when he needs all his coolness and self-possession.

The wearing sense of responsibility weighs upon every conscientious manager. I can well remember, at a launch of our own, a colleague, a man of great experience, exclaiming to me, as the ship took the water, "I *do* enjoy another man's launch." There was a world of meaning in that remark,—a very pleasant one as an indirect expression of sympathy.

The problem that the shipbuilder has to solve in launching, is the transfer of a huge, unwieldy, heavy mass from *terra firma* to the water. Small vessels are simply dragged down, by what is called Scotch science, defined by Americans to be "main force and stupidity," over the pebbles of the beach or over wooden rollers, and such was probably the practice of the ancients. But even they had to have recourse to mechanical means when their ships attained a certain size. They probably used some sort of windlass, actuating a great many hauling ropes,—at least that is the sort of machine Archimedes is reported to have designed for the purpose, and mention of which is made in Plutarch's "Lives Under Marcellus." It introduces us to our modern system.

Nowadays, in vessels of any size advantage is taken of the energy of position of the ship on the stocks, as measured by the difference of the height of the centre of gravity of the vessel on land and afloat. A ship is supported on wooden keel blocks at a certain distance above the ground. In the slow process of construction, piece by piece of metal and wood is raised up and built into the vessel, and the result of the sum of all these lifts is that the general centre of gravity of the whole structure is many feet above the ground,



A LAUNCHING CRADLE.

constituting a force, available for launching, just as a loose boulder is ready to be pushed down a hill. In a certain sense, therefore, we may say that the operation of launching begins with the first step in the construction of the ship.

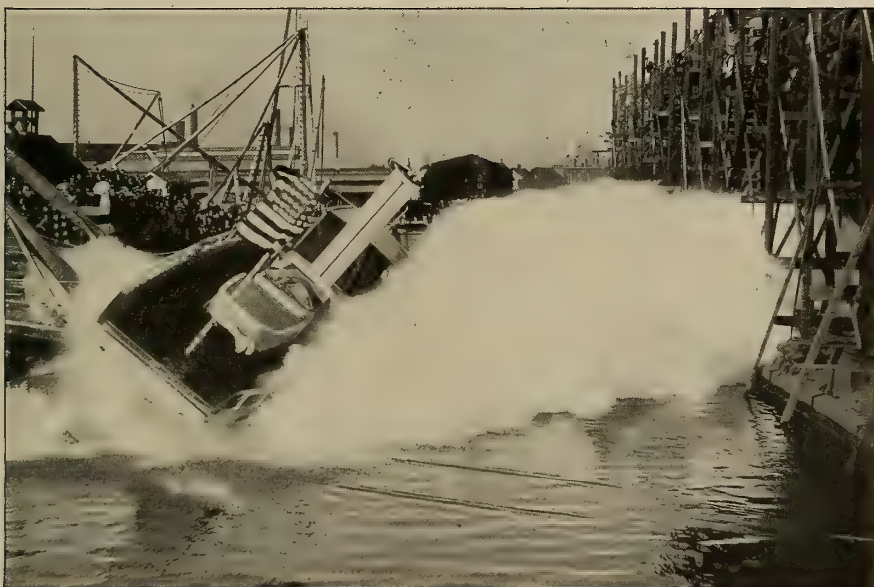
In launching we have to move the mass not only down, but along. The ship is generally, but not necessarily, built at a greater or less inclination, longitudinally, towards the water. She might be on even keel or have an opposite inclination, or, indeed, be in any position, if there were any good reason for a deviation from ordinary practice. But, as a rule, the ground slopes naturally downwards to the water's edge; the ways must, as we shall see, slope in the same direction; and it is probable that the more nearly these three declivities, *i. e.*, of the ground, the ways and the ship, approach coincidence the less the cost of supports and launching material.

The ways are really roads down which the ship travels to the water. They correspond to the rails of a railroad; but since the rails are arranged in view of rolling, and the ways of sliding, friction, a rather different construction is

called for. They are generally two in number, one on each side, although in Mediterranean and Adriatic ports more are adopted on what is called the Venetian system. These ways are spaced about one-third of the ship's beam from one another, and are composed of two members, the permanent or standing and the sliding ways. They are made of wood, preferably of oak, and run longitudinally in so far as concerns the sliding ways, about seven-eighths the length of the ship.

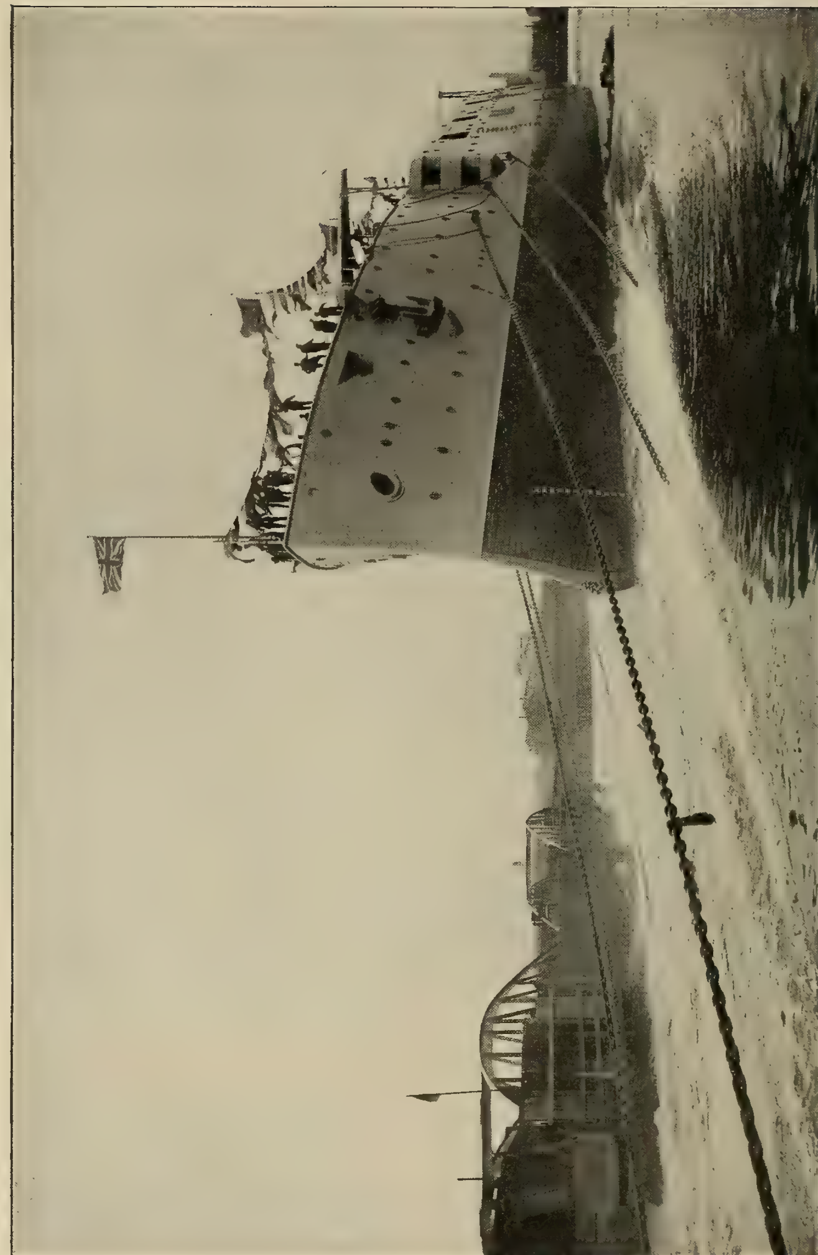
The length of the standing ways depends primarily on the fall of the bed of the river or sea into which you are launching; but as it enters into the determination of certain of the statical conditions involved in the operation, it is well to consider it in its relation to them. The weight to be borne, in great measure determines the width of the ways. It is not generally desirable to have a higher initial pressure on the ways than two tons per square foot.

Fig. 1 gives a characteristic curve showing the variation in the pressures as the ship travels down, on the assumption that the weight under consideration is uniformly distributed over the whole area of contact of sliding and standing ways at any given moment. That assumption is not, however, a fair one. Indeed, it can easily be shown that when the vessel is approaching the dropping off point, uniformity of distribution of pressure is impossible. The curve shows the rate of change of land-borne weight into displacement relatively to contact surface of ways. When the curve rises, surface is being run off more rapidly than land-borne weight, and, conversely, when it falls, weight is being run off more rapidly than surface. If weight and surface were run off at an equal rate the curve would of course be a horizontal straight line.



A SIDE LAUNCH IN THE GREAT LAKE DISTRICT IN THE UNITED STATES.

The principle of launching is that of gravitation force down an inclined plane, involving, among others, the resistance due to the friction between the surfaces of the ways in contact. This is very difficult of determination, except for about the first half of the travel down the ways, after which, owing to the impossibility of evaluating exactly the re-



FROM A COPYRIGHTED PHOTO BY MACLURE, MACDONALD & CO., GLASGOW.

AFTER A LAUNCH AT THE YARD OF THE FAIRFIELD ENGINEERING AND SHIPBUILDING CO. LTD., GOVAN, GLASGOW.

LAUNCHING THE "CALEDONIA," AT THE YARD OF MESSRS. CAIRD & CO., AT GREENOCK, SCOTLAND.

sistance the ship encounters in forcing its way into the water, the resistance due to the friction of the surfaces of the ways, in the absence of experimental data, remains tied up with it. The total resistance due to the two causes we know, but we cannot separate them. In order to reduce the co-efficient of friction to a minimum, the surfaces in contact are carefully greased. Various lubricating substances are recommended, and mutton tallow finds votaries

THE P. & O. COMPANY'S STEAMER "INDIA" ON THE STOCKS IN THE YARD OF MESSRS. CAIRD & CO.

THE STERN OF H. M. S. "SANS PAREIL," BUILT BY THE THAMES IRONWORKS & SHIP-BUILDING CO., LTD., LONDON.

who decry beef tallow, while many builders patronise advertised mixtures. If it were possible to get complete and reliable tests of pure Russian tallow at a pressure of thirty pounds per square inch and a velocity of twenty feet per second, so as to get its co-efficient of friction on launching conditions, I should rather use it than anything else. The only published results of tests at all approaching to the above conditions are those of Mr. C. J. H. Woodbury, which appeared in the Transactions of the American Society of Mechanical Engineers in 1880 and 1885.

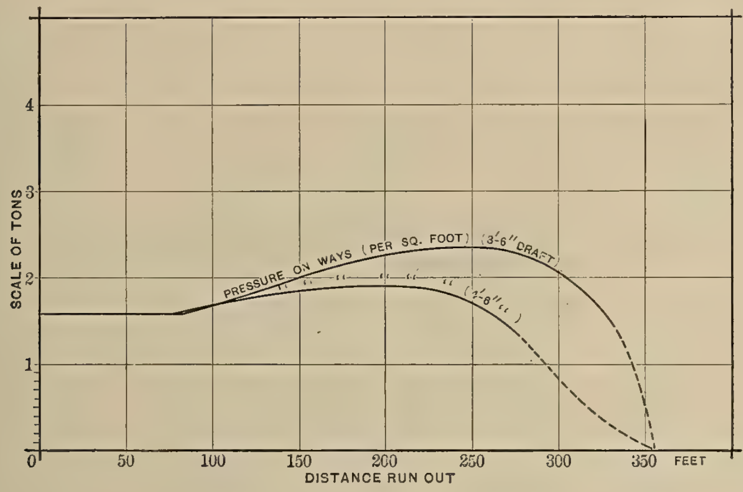


FIG. 1.

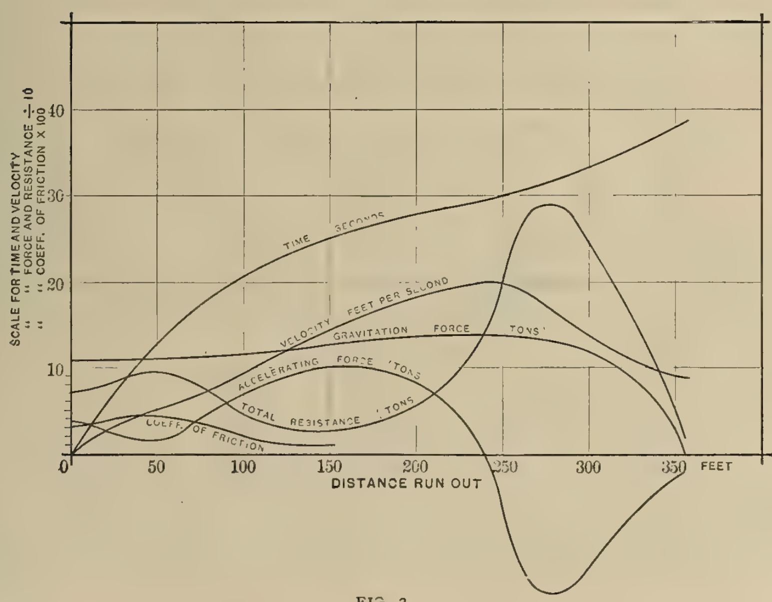


FIG. 2.

He experimented with a mineral oil of 0.888 specific gravity, at a constant velocity of five feet per second, at pressures varying from one to forty pounds per square inch, and at temperatures

LAUNCH OF H. M. S. "VENUS," AT THE YARD OF THE FAIRFIELD ENGINEERING & SHIP-BUILDING CO., LTD.

from 40 degrees to 100 degrees F. The machine he designed for these tests would, I should think, be suitable for testing tallow under conditions of varying velocities, running up to, say, thirty feet per second, and a large range of temperatures and pressures.

The mean angle of inclination of the ways is generally fixed empirically at something like one in twenty-four for a heavy ship. It is a common practice to make this angle a progressive one by cambering the ways with the effect of diminishing the initial and increasing the final velocity of gliding. It has, however, the deleterious effect, quite appreciable by measurement, of setting up alternate hogging and sagging stresses in the ship in the act of accommodating herself to the curved ways and then of hinging about the fore end of the forward cradle when the stern begins to rise. The first, or hogging, stress could be avoided if the camber were set out as the arc of a circle; the second or sagging strees is always present, but it is a minimum with straight ways. This is, however, one of those controversial points that can only be treated effectively in a purely technical discussion.

The ways having been laid, a cradle is built up at the forward and after ends of the vessel to bring the weight of these tapering ends down upon the ways and the uprights or poppets of these cradles are tied across to one another to counteract the resultant outward pressure due to the angle at which the ship rests on them. The ways are wedged close up to the skin of the ship, and a few hours before the launch the keel and bilge blocks are gradually removed and the whole weight of the ship is taken on the ways while its downward tendency is checked by dog shores.

There is another element which, in tidal waters, such as the Clyde, must be taken into account, namely, the height of water over the end of the ways. The mean variation of height of water at spring tides is about two feet, so that, when you have arranged for a certain height, prudence requires that your conditions should be such as to make the launch safe at a foot above and a foot below that limit at least.

When all is ready, at the word of command, "Down Daggers," the dog shores are knocked out and the ship is free. As a rule, she moves very slowly at first, but although the motion may be imperceptible it is relentless and irresistible. In the case of H. M. S. *Ramillies* no means at the command of the builders were sufficient to arrest her

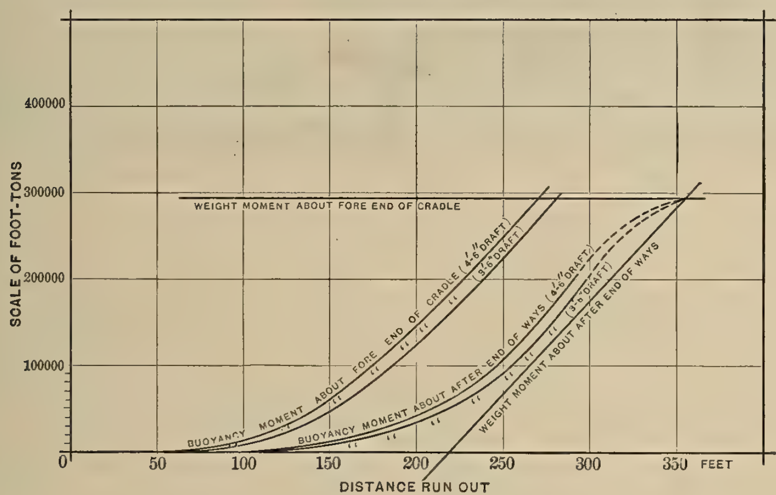


FIG. 3.

LEAVING THE LAUNCHING WAYS.

motion, although it could not be detected by the eye. Iron dogs were straightened out like rope. The velocity curve in Fig. 2 shows the rate at which the speed of travel increases and diminishes, and is very instructive,—in fact, it furnishes the key to the analysis of the whole operation.

The launch of a 7000-ton ship, weighing 5000 tons, and travelling some 550 to 600 feet, occupies about forty seconds from the time the dog shores are released till the drags come into play. The extensive preparations, the careful calculations, the costly ways, all are made for two-thirds of a minute's work. The two illustrations on page —— show the P. and O. steamers *Caledonia* and *India*. The one at the top of the page is specially interesting on account of the smoke at the bows,—an evidence of the high temperature to which the work in overcoming friction had raised the launching tallow.

Fig. 3 is one of statical elements and Fig. 2 of dynamical elements, and both, I think, explain themselves. They are given merely as a suggestion of convenient form and not as conveying authentic information, although they have been worked out from an actual case. Complete forms, carefully worked out for every launch, are of great value. You cannot tell what the effect of some apparently trifling change may be until you have traced it through all the curves, and you cannot afford, in an operation of such magnitude, to leave anything to chance if you expect your ways to be "ways of pleasantness."

HYDRAULIC PRINCIPLES AFFECTING A FLOATING SHIP.

By F. P. Purvis.

ABSTRACT science is rarely the precursor of invention, and many ships must have floated on all the available waters of the world long before Archimedes first enunciated the principle that the weight lost by a body in water must be equal to the weight of the water displaced. But although abstract science can claim none of the honours of the inventive faculty, it does the very important duty of getting all that is possible out of an invention, and of allowing correct forecasts to be made of what may be expected under a known combination of circumstances.

The foregoing remarks are peculiarly applicable to the hydrostatics and hydrodynamics of a ship. Whatever may have been the case in the past, it is not now necessary to actually build a ship in order to find out what cargo she will carry, or at what speed she will travel, whether she will prove crank or stiff; or, if a sailing ship, how she will stand up to the wind. Of course, all ships do not equally fulfil the intentions of their designers, and the non-fulfilment may be put down to blundering, but as long as invention is allowed to play any part in a design there will always be something to learn and some chance of the lesson being, in the first instance, of a not pleasant nature.

Probably the simplest form of a floating body we can imagine is an ordinary box or block, with square angles. If it floats with its bottom parallel to the water surface, the weight of the water it displaces can be readily calculated; the product of length, breadth and draught gives the volume of the displaced water, and this volume, in cubic feet, multiplied by 62.4, gives the weight in pounds, or, divided by 35.9, gives the weight in tons, provided the water be fresh, the above figures being altered, respectively, to 64 and 35 if the water be sea water of ordinary density.

Far as a square-edged block may appear from representing the form of a ship, it is astonishing how closely some ships approximate to it. Take such a body and cut away the angles so as to remove some 18 per cent. of below water portion, and the correct displacement of some modern cargo carriers will be arrived at. The ratio between displacement of a ship and displacement of a block having the same length, breadth and draught from top of keel is a measure very often referred to in shipbuilding parlance as the "block co-efficient," and varies from somewhere about 0.4 in yachts and vessels of special type, to 0.82 in the fullest cargo steamers.

In any ship there are two very important conditions of draught about which it is desirable to know all that is possible. The first is the "light draught," or draught at which she floats when empty. There are some differences of opinion as to what should be included in the "light" weights upon which "light" draughts depends, but these weights are generally taken to include all the permanent weights of which hull and machinery are comprised, together with the water in boilers, condenser, etc., when in usual conditions of steaming, and to exclude all cargo, coal, stores, bilge water and other

FIG. 1. THE STEAMER "GEORGIC" OF THE WHITE STAR LINE. BUILT IN 1895 BY MESSRS. HARLAND & WOLFF, LTD., BELFAST. MOULDED DIMENSIONS, 560 X 60 X 38 FEET. CARRIES A DEADWEIGHT OF 12,000 TONS ON A DRAUGHT OF 24 FEET.

weights not actually forming a part of the hull and machinery.

The second is the load draught, or extreme draught to which it is deemed safe or efficient to load the ship. This load draught depends on a number of considerations, and is now in Great Britain a matter of legislative cognisance. To know what load or deadweight any ship will carry, it is only necessary to know the displacement corresponding to the load draught, and that corresponding to the light draught, and to subtract the latter from the former.

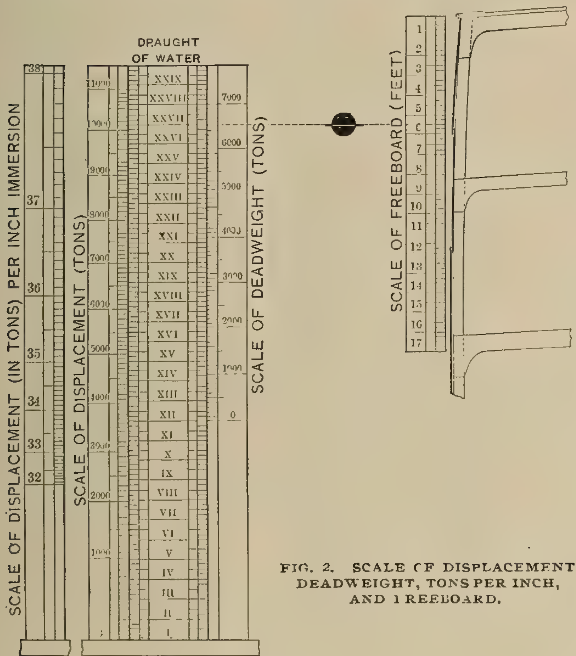


FIG. 2. SCALE OF DISPLACEMENT DEADWEIGHT, TONS PER INCH, AND FREEBOARD.

As a matter of fact, it is usual to know the displacements and loads or deadweights at all possible draughts and to represent them in the form of a curve or a scale. Of late years the enormous deadweight capability of a large number of the steamers built has been one of the features of shipbuilding. It is only necessary here to mention the steamship *Georgic*, built in 1895 for the White Star line, by Messrs. Harland and Wolff, of Belfast, Ireland; in a length of about 560 feet she carries, at load draught, a deadweight of 12,000 tons.

It has been often pointed out that the most economical way of getting an increase of deadweight is by an increase in draught of water. This depends on two conditions:—(1) that the depth of water is sufficient in the rivers or ports between which she has to trade; and (2) that the ship is deep enough to allow the increase and yet leave her sufficient freeboard, or side out of water. The first condition involves very important local considerations; the second involves the limit beyond which draught cannot be carried.

In an ordinary ship the depth cannot be made more than a certain ratio of the breadth, say 7-10ths, or there will be trouble with the stability; out of this depth again a certain portion (say 15-100ths) of breadth is required for freeboard, leaving 55-100ths for draught of water. From the above considerations it would appear, as pointed out by the late William Denny in his Watt lecture at Greenock, in 1882, that while draught of water can never much exceed 55 per cent. of the beam of the ship, it should, for economy of construction, in a deadweight carrier, be allowed to approach as near as possible to this limit.

It is a matter of common observation by all engaged in the practical loading of a ship, that as the draught increases so the weight required to immerse her still further by a given amount (say 1 inch) also increases. A common expression is to say that the ship is "coming to her bearings." Like a good many similar truths, this one is often exaggerated. A tons-per-inch curve is generally got out in the drawing office, and it partakes the character of a mean cross section of the ship.

A specimen of such a curve is given in Fig. 4, measurements up the line *A B* being draught of water, and at right

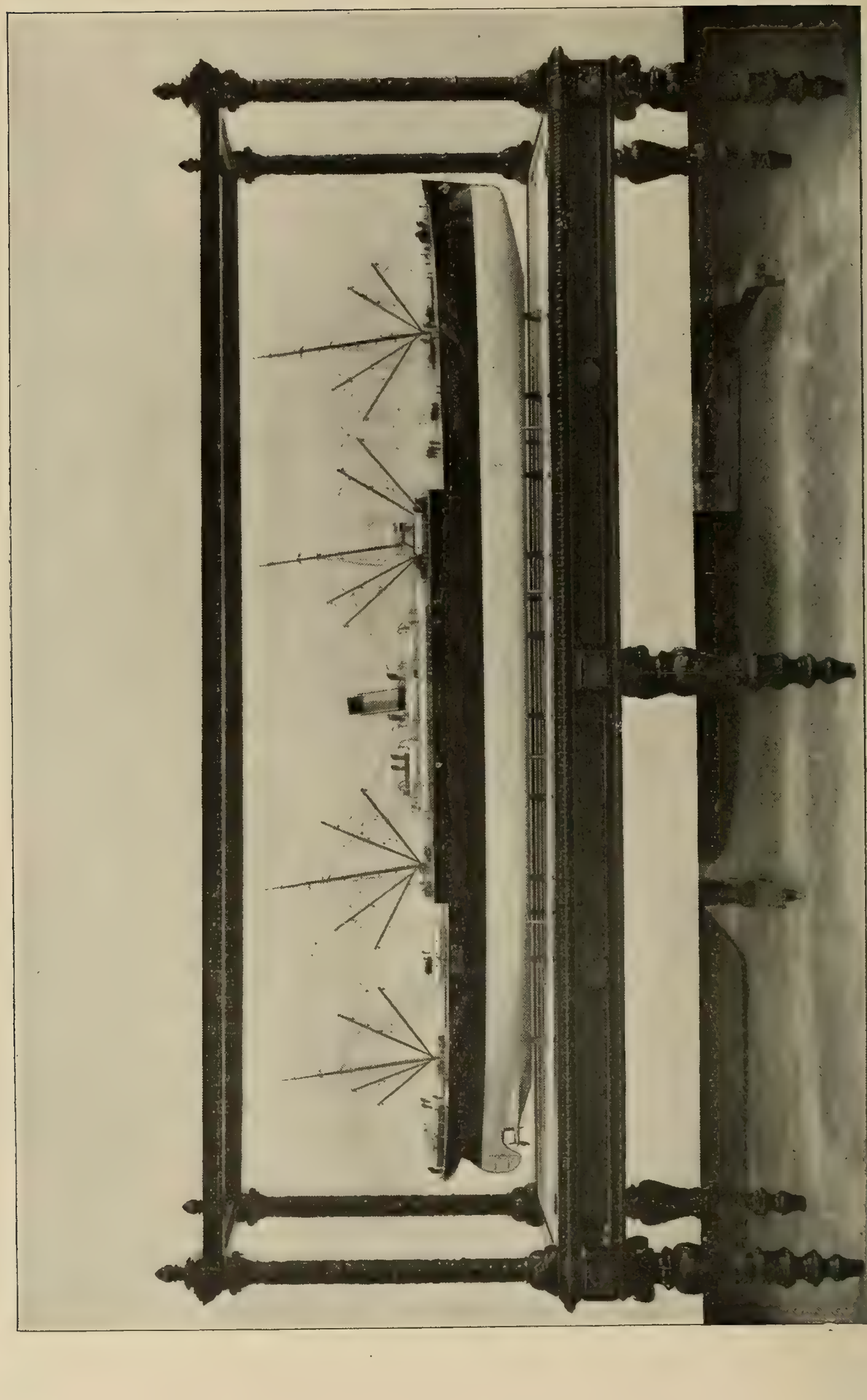


FIG. 3. MODEL OF THE STEAMER "GEORGIC."

angles to the line *A B*, tons per inch. Applying a scale to this diagram, it will be found that while at 20 feet draught the tons per inch are 36.4, at 26 feet draught the tons per inch are 37.5, or a difference of 3 per cent., a tangible, but by no means enormous difference in the tons per inch due to a very large difference in the draught of water.

A principle of hydrostatics second to that of Archimedes only in that it is usually considered after the former, is that the centre of gravity of the ship must lie in the same vertical line with the centre of gravity of the water displaced. If for any reason the centre of gravity of a ship lies out of the centre plane, the ship will take a list to that side on which the centre of gravity lies, such that the water then displaced will have its centre of gravity in the same vertical line with the centre of gravity of the ship.

Again, a ship will trim with keel parallel to the water line—*i. e.*, with same draught of water both forward and aft, only if the centre of gravity of displacement in this condition is in the same vertical line with the centre of gravity of the ship. Supposing such condition to obtain, and weight, in the form say of ballast or cargo, to be moved from one position to a position farther aft; the trim will then be altered until the centre of gravity of displacement is moved aft, so as to come in the same vertical line with the new centre of gravity of ship. On this matter of trim I shall have some more to say a little further on.

Besides the conditions that weight must equal buoyancy, and centre of gravity and centre of gravity of displacement (centre of buoyancy as it is generally called) must be in the same vertical line, there is still another condition necessary. Centre of gravity in nearly every floating body lies above centre of buoyancy, and yet the body is not top-heavy in the sense that it will turn over. The last condition alluded to takes account of this peculiarity; it depends upon the consideration that any angular change (say in the transverse direction) given to the body, at once changes the centre of buoyancy and the direction of the line of support.

This being so, the condition required for the avoidance of top-heaviness is that the line of support, when shifted by reason of a small angle of heel shall lie to the inclined side of the centre of gravity. Metacentre is the point where this shifted line of support intersects the original when the angle of heel is infinitesimally small; and the condition just enunciated may be equally well expressed in the usual form by saying that to avoid top-heaviness the centre of gravity must lie below the metacentre.

To take examples from a few simple

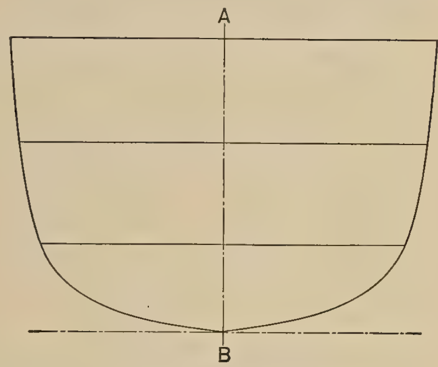


FIG. 4. MEAN CROSS SECTION OF SHIP.

forms, I may mention first, forms having circular sections, such as a sphere, or a cone, or a cylinder. In the sphere, the metacentre,—whatever the draught,—is always the centre of the figure; in a cone or cylinder it lies in the axis, so that with forms having these figures, if they are so loaded that the centre of gravity is not quite in the centre or axis, their position of rest will be such as to place that centre of gravity vertically below the centre or axis.

In bodies having rectangular sections there are some very curious changes of condition resulting from changes of draught. If the section is square, as in an ordinary log of wood, the metacentre lies above the centre of the square as long as the draught does not much exceed 21 per cent. of the breadth or depth of the square; as the draught

gets beyond 21 per cent. of the depth, the metacentre falls below the centre, and remains below until the draught reaches 79 per cent. of the depth; it then rises again above the centre of the square, and continues to rise as long as any part of the square is out of water.

Common observation bears out the truth of the foregoing statements. A log of yellow pine, which floats about half immersed, is never seen floating with its upper surface level, but always corner up or as near an approach to this as its symmetry will allow. A log of oak, on the other hand, or of heavy teak, floats with its top surface level on account of its extra draught and the changed position of the metacentre. The same would happen with a log of wood sufficiently light to float with the limited draught mentioned above, and does happen with, say, an empty trunk floating sufficiently light to satisfy that condition.

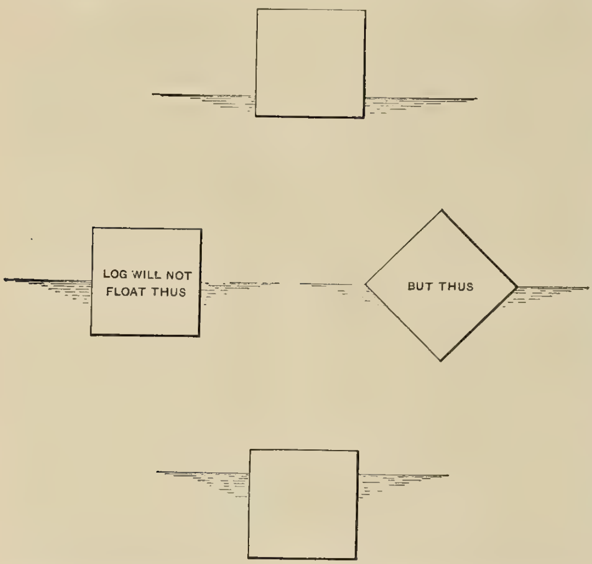


FIG. 5. LOGS OF WOOD FLOATING AT DIFFERENT IMMERSIONS.

Metacentric height as the distance or interval is called between metacentre and centre of gravity, is a most important measure of the stability of a ship. In many cases where the type of ship is not out of the common, or the draught of water abnormal, it is the only measure of which it is practically necessary to take any account. The value that it should possess, varies greatly with the type of ship.

In a steamer with plenty of freeboard, a metacentric height of a few inches only is sufficient; indeed, ships have been known to sail with a negative metacentric height or with centre of gravity above the metacentre. In an ordinary cargo steamer the metacentric height may be about one foot; in special steamers, designed to carry a very large number of passengers, it may range from 2 feet to 4 feet, according to the nature of the service and the size of the steamer; while again, in a sailing ship it should not be less than 3 feet.

I have used the word top-heaviness in relation to the metacentric height. This expression is, however, a very elastic one as ordinarily applied. A ship may stand perfectly well when upright, and when listed a little either way may return unerringly to the vertical. But what will happen when from wind, or waves, or any other cause, the angle of heel gets beyond the initial stages? The quesion whether the vessel will still right from the angle or go further over still depends upon whether the line of buoyancy at that angle lies to the inclined side of the centre of gravity or the reverse, but the knowledge of the relative positions of metacentre and centre of gravity may give no guide with regard to this. Other calculations have then to be made which need not be described here. Results are obtained which are usually set off in the form of a curve, such as Fig. 6, in which measurements along the line o to 90 degrees give the angle of heel, and measurements square to the line o to 90 degrees give the righting arm, or horizontal distance between centre of gravity and the direction of

the vertical through the centre of buoyancy of the ship as listed. Sometimes, and in some way more accurately, the curve set off is one of righting moments instead of righting arms. The weight of the ship downwards and the displacement upwards form a couple, and the product of displacement and righting arm for any angle gives the righting moment.

Fig. 6 gives the curve of righting arms for a high freeboard ship having 12 inches of metacentric height. Fig. 7 gives it for the same ship when the metacentric height is a negative quantity, the metacentre lying 12 inches below the centre of gravity. Measurements below the line 0 to 90 degrees are to be taken as negative, and as the curve crosses 0 to 90 degrees at 25 degrees, the meaning is that the ship will not stand upright, but will list either to port or starboard a matter of 25 degrees, after which she becomes perfectly safe and possesses a reserve of stability largely in excess of what is sufficient. Fig. 8 again gives the righting arms for a shallow ship having a large amount of metacentric height. The angle of heel, corresponding to which the curve of righting arms cuts the line 0 to 90 degrees (at 55 degrees in Fig. 8) is the angle at which the righting arm becomes zero, and beyond which it becomes negative, so that, while the ship, if inclined in still water as far as 55 degrees, would return to the upright, it would, if inclined beyond 55 degrees, move farther from the upright, and probably turn over.

I say, probably turn over, because this is not necessarily the case; it is possible to have a curve of stability or righting arms, such as shown in Fig. 9. In this case the ship would stand upright; if slowly inclined to 8 degrees, she would of herself move farther from the vertical, and if allowed to do this slowly, she would come to rest again at 15 degrees; if again slowly listed up to 28 degrees, she would again of herself move farther from the vertical until again coming to rest at 63 degrees.

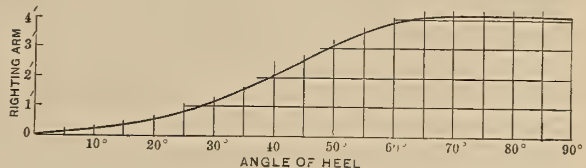


FIG. 6.

FIG. 7.

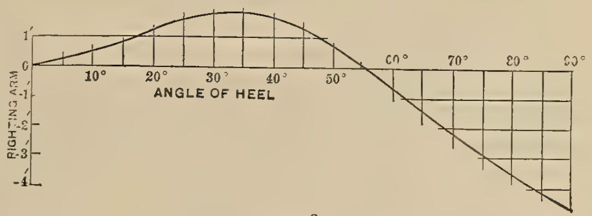


FIG. 8.

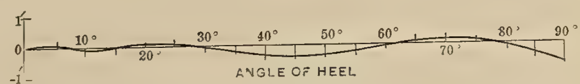


FIG. 9.

CURVES OF STABILITY.

These peculiarities would be traceable in whichever direction the listing took place, whether to port or starboard, the result in a symmetrical body being, of course, the same whichever the direction moved in.

I spoke above of the effect on trim of shifting weights in a forward and aft direction. Just as in shifting weights transversely, the angle of heel depends very largely on the transverse metacentric height, so the alteration of trim depends on the longitudinal metacentric height, the metacentre depending on the same principle as before, but the application of the principle being now made in the longitudinal di-

rection instead of in the transverse. So far I have dealt with the problems of flotation, and I now turn to another subject and take up some of the problems connected with speed, especially the speed of a steamship. The resistance to the passage of a shapely body through the water has been proved to be chiefly due to two causes,—(1) the friction of its immersed surface, and (2) the formation and maintenance of waves; as fresh lengths of waves are continually being formed a continual expenditure of energy is being required. Attempts have been made to show theoretically the limits of shape within which other causes of resistance are reduced to a minimum, and actual experiments with models confirm the theoretical investigations in proving that the two above causes usually largely preponderate.

When a body, as a submarine boat, is towed or propelled below the surface of the water, the friction due to the second cause mentioned, viz., the wave making resistance, may be greatly diminished and even eliminated altogether.

The usual case of a ship is, of course, one in which only a portion is submerged, and then the two causes of resistance mentioned above operate conjointly. The value of the friction element per square foot of surface exposed to its action varies with the length; it also varies with the speed, the variation in this case being not quite as the square of the speed; for a speed of 10 knots the friction per square foot of a clean painted surface is ¾ pound for a surface 12 feet in length, and 6-10ths pounds for a surface from 300 to 600 feet in length.

The value of the element due to the maintenance of waves, is almost negli-

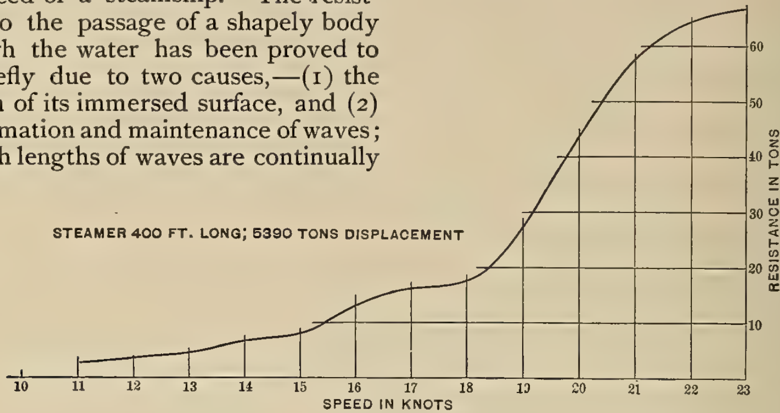


FIG. 10. HUMPS AND HOLLOWS IN THE CURVE OF WAVE-MAKING RESISTANCE.

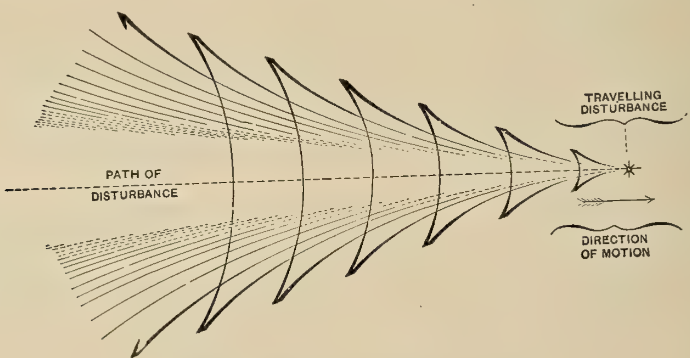


FIG. 11. ECHELON SERIES OF WAVES.

gable at low speeds, but mounts up at an enormously increasing rate as the speed increases. As we shall see by and by, there is a special advantage in relating speed to the square root of the ship's length, and it may be said here, as a rough guide to the amount of this element of resistance, that when the speed in knots is equal to the square root of the length of ship, taken in feet, the wave-making resistance is, in most cases at least, well under one per cent. of the displacement of the ship.

The late William Froude, F. R. S., LL.D., in his investigations and experiments, showed that difficult as it might be to express any law of the growth of this resistance with increasing speed, it is comparatively easy when the wave-making resistance of a ship is known at a certain speed, to find the resistance of an exactly simliar ship at another speed related to the first as the square root of the lengths; in that case the wave-making resistance varies as the displacement.

Model experiments alone can, in practice, be relied on to give the growth of resistance with increasing speed, and of published results the most interesting are those of Mr. R. E. Froude, F. R. S. This investigator showed that in the growth of resistance with speed there is, at certain well definable speeds, an abnormally large increase and at certain other an abnormally small increase of wave-making resistance such as to give to a curve, constructed to represent the growth, a succession of "humps" and "hollows" at those speeds. He also showed to what these abnormal variations were due. Of this I shall have more to say later on; at present I give the annexed table, based upon his figures, aiming at showing, for ships of different lengths, the speeds at which the growth is abnormally great.

Lengths.	Speeds.		
	Knots.	Knots.	Knots.
800 feet	41¾	27½	21¾
750 "	40½	26½	21
700 "	39¼	25¾	20½
650 "	38	24¾	19¾
600 "	36½	23¾	18¾
550 "	35	22¾	18
500 "	33¼	21¾	17¼
450 "	31½	20¾	16¼
400 "	29½	19½	15½
350 "	27½	18¼	14½
300 "	25½	17	13¼
250 "	23¼	15½	12¼
200 "	21	13¾	11
150 "	18	12	9½
100 "	14¾	9¼	7¾

The practical value of this table is that it points out the speeds at and about which a little increase of speed is obtained only with great difficulty and a large expenditure of power. As contrasted with the above I give also the following table, showing the speeds at which the growth of resistance is abnormally small.

Lengths.	Speeds.		
	Knots.	Knots.	Knots.
800 feet	32¼	24¼	20
750 "	31¼	23½	19½
700 "	30¼	22¾	18¾
650 "	29¼	21¾	18
600 "	28	21	17½
550 "	26¾	20	16¾
500 "	25½	19¼	16
450 "	24¼	18¼	15
400 "	23	17	14¼
350 "	21½	16	13¼
300 "	19¾	14¾	12¼
250 "	18	13½	11¼
200 "	16¼	12	10
150 "	14	10½	8¾
100 "	11½	8½	7

The speeds in these two tables are not the speeds at which the "humps" and "hollows" respectively occur, but the speeds between the "hollows" and "humps" in the one case where the curve of wave-making resistance is rising most rapidly, and the speeds between "humps" and "hollows" in the other where the curve of wave-making resistance is rising least rapidly.

One of the very curious discoveries of late years in connection with waves is Lord Kelvin's échelon series and the meaning of it. This series is best observed when the simplest possible body, such as a sphere, is drawn through the water; it is rather obscured in the case of a ship by the presence of more than one series, initiated at more than one point in the length of the ship. Fig. 10 shows something of the general form of the series. The disturbance at the body itself forms the first element; the complete triangular figure forms the second, and so on.

It is a well-known feature of ordinary wave motion that an isolated wave form does not exist, but that the energy of a wave form is being perpetually transferred to another and another wave at the rear of the first, thus causing a train

FIG. 12. THE STEAMER "MARGARITA" AT THREE DIFFERENT SPEEDS, SHOWING HOW THE CRESTS OF THE WAVES CHANGE THEIR POSITION AS THE SPEED INCREASES.

of waves. Now the disturbance at the body appears to satisfy itself by starting a wave in every angular direction; each of these is followed by its train, with the result that all the second waves of each train are connected together into an element, the different portions of which face in all directions, from the two directions at right angles to the line of motion to the direction in the line of motion.

The outline form of this element also is determined by the fundamental principle of wave motion that there is a distinct connection between a wave length (*i. e.*, a length from crest to crest) and the square of its speed, lengths in the case of each portion of ridge of the element having to be measured by taking a normal distance between the first disturbance and the tangent line at the ridge at the portion in question, and speed being taken in the direction of the same normal. The third element is produced, in a similar way, by a combination of all the third waves of each train, and so on.

In the case of a ship, as I have already said, the échelon series arising from disturbance at the bow is obscured by the presence of other series, but, though obscured as far as the eye is concerned, the portions of it which travel in the same direction as the ship have a very marked influence on the resistance of the ship, and the humps and hollows of which so much has already been said depend upon whether a trough or a crest of that series happens to occur at a certain region in the run or after body, where its influence is most effective towards causing a drag or giving a forward pressure to the ship.

I have referred a good deal to model experiments, and it is now desirable to mention them more specially. Experiments, carefully conducted with ship-shape and other forms, have often been made in the past. It is only necessary here to mention the names of Beaufoy and of Scott Russell as notable examples. Model experiments and methods which are now regarded as the only valuable methods, were devised and first carried out by the late William Froude, F. R. S. L. L. D. He began in a crude way, with models dragged alongside a steam launch, and subsequently, in a tank which he constructed for the British Admiralty at Torquay, he made experiments of great value. His work is still being continued for the Admiralty by his son, Mr. R. E. Froude, F. R. S., in a tank 400 feet long, constructed under his directions at the Haslar Gunboat Yard.

The models used in these experiments vary in length according to circumstances, 12 feet being a good representative of this dimension. They are usually perfectly ship-shape, below water, and generally represent the forms of actually existing ships or of designs. Experiments with each model are taken at a vast number of speeds, the speed required being carefully obtained and maintained during each several experiment; and by a beautifully contrived dynamometer the resistance to the model's motion is most carefully measured and recorded during each experiment.

From the speeds and resistances so obtained a curve is constructed, and the full expression of the relation of the two is given between the limits of speed for which the information is required. Having obtained the information for the model, it is interpreted for the ship represented, in terms of the principle already mentioned, viz., that at speeds of ship and model related to one another as the square root of the length, the wave-making resistance varies as the displacement.

Taking a concrete example and supposing the wave-making resistance of a model 12 feet long, at 2 knots, to be 1 pound, then the wave-making resistance of a ship 300 feet (12×25) long, at 10 (2×5) knots would be 25^3 pounds (15,625 pounds). In this case, as the ship is twenty-five times as long as the model, the square root of which is 5, the relation of "corresponding speeds" is 5 to 1, so that 2 knots for the model "corresponds to" 10 knots for the ship, and the relation of displacement and also of resistance is 25^3, or 15,625 to 1.

Besides the Haslar tank for the use

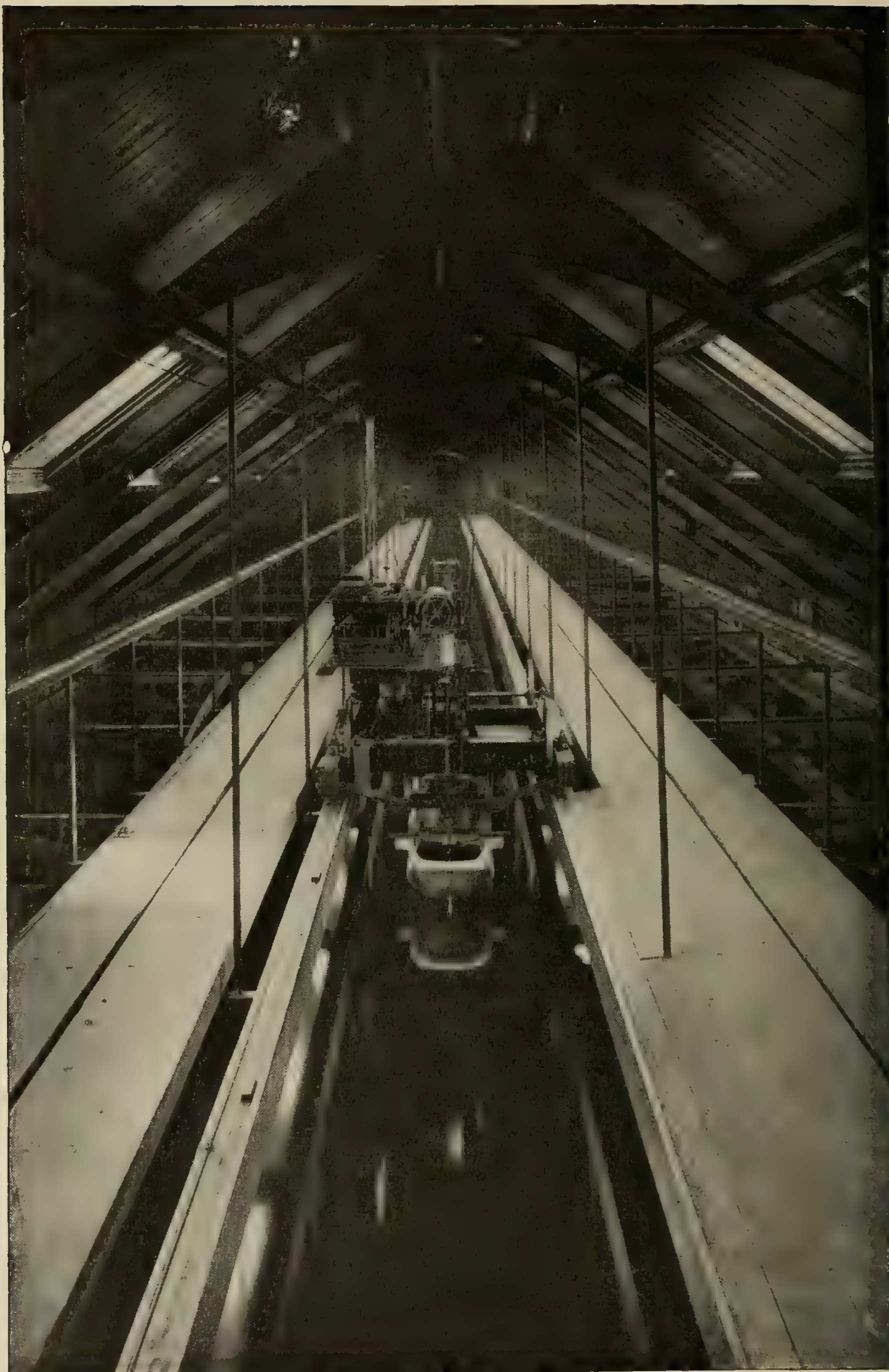


FIG. 13. THE EXPERIMENTAL TANK OF MESSRS. WM. DENNY & BROS., AT DUMBARTON, SCOTLAND.

of the British Admiralty there are four other government establishments abroad worked upon the same, or similar, methods, viz., Dutch, Italian, Russian and French, all of which, except the French, have borrowed their design and methods largely from the British Admiralty and the Messrs. Froude.

There is, besides, the experimental tank, constructed for their own private use, by the Messrs. William Denny & Bros., at Dumbarton, Scotland, to which the same remarks apply, and by the kind courtesy of Messrs. William Denny & Bros., I am able, in Figs. 13 and 14, to present two views, showing the general appearance of the tank and dynamometer apparatus with a model in place. In these tanks, besides the relation between resistance and speed, other matters can be, and are, investigated, the matter of the propeller (both paddle and screw) and its effect, when size and design are varied, being among the most important.

From time to time discussion has taken place as to the desirability of having a public tank, conducted by an official, either as a personal venture or under support of a subsidy, the tank to be open for the use of all shipbuilders and others feeling the need of appeal to it. The fear of the jealousy of rivals, which would prevent one shipbuilder from sending for experiment the lines of a ship which he did not wish another to see, has sometimes,—I think unworthily,—been pleaded as a reason against such a public tank. Such a reason, I think, shows some misapprehension of the chief advantage to be derived from a tank, and the experimental results obtained from it.

The chief advantage, as it seems to me, lies in accumulating information and having it in a well digested form, ready for immediate use when required. When that is the case, as it is at the Haslar and at Messrs. Denny's establishments, as soon as ever a problem is presented, it can be solved with a pretty close approximation without any further experiment whatever being made, the accumulated data being quite sufficient for the purpose. If, for instance, all the dimensions and displacement of a steamer be fixed and the problem be that of finding the power necessary for a certain speed, selections can be made from the data of such models as most nearly represent the vessel required. The displacements of the steamers thus represented will probably vary both upwards and downwards from the displacement required, and a little judicious interpolation, by means of curves or otherwise, will give the required solution.

In important cases it will, no doubt, always be desirable to check an approximate solution, obtained as just indicated, by further experiments, made on an actual model exactly representing the proposed steamer, but the more carefully data have been obtained and arranged from general experiments, the less the necessity for experiment with the special model. Very many of the questions which puzzle a designer could never be allowed time enough for solution by a special experiment; if they cannot be answered by some ready means they must necessarily go unanswered altogether for the time.

The advantage as regards speed and power of a small additional length, or breadth or draught, or of finer lines; or the relative advantage, displacement being fixed, of an increase of breadth with a view to allow of finer lines, are among these puzzling questions. Given only sufficient tank data, they can be answered without special experiment; and in many cases at least it is not too much to say that the possession of every facility to have them answered by special tank experiment would not insure their being so answered, the time involved being prohibitory.

While then it is not part of my object to appeal for the establishment of a public tank, I cannot but point out that such a tank would be of the greatest service to a large number, and that the objection, on the score of jealousy of rivals, should not be and need not be a serious objection to its value as a working institution.

In the matter of getting, from speed trials of actual ships, information which

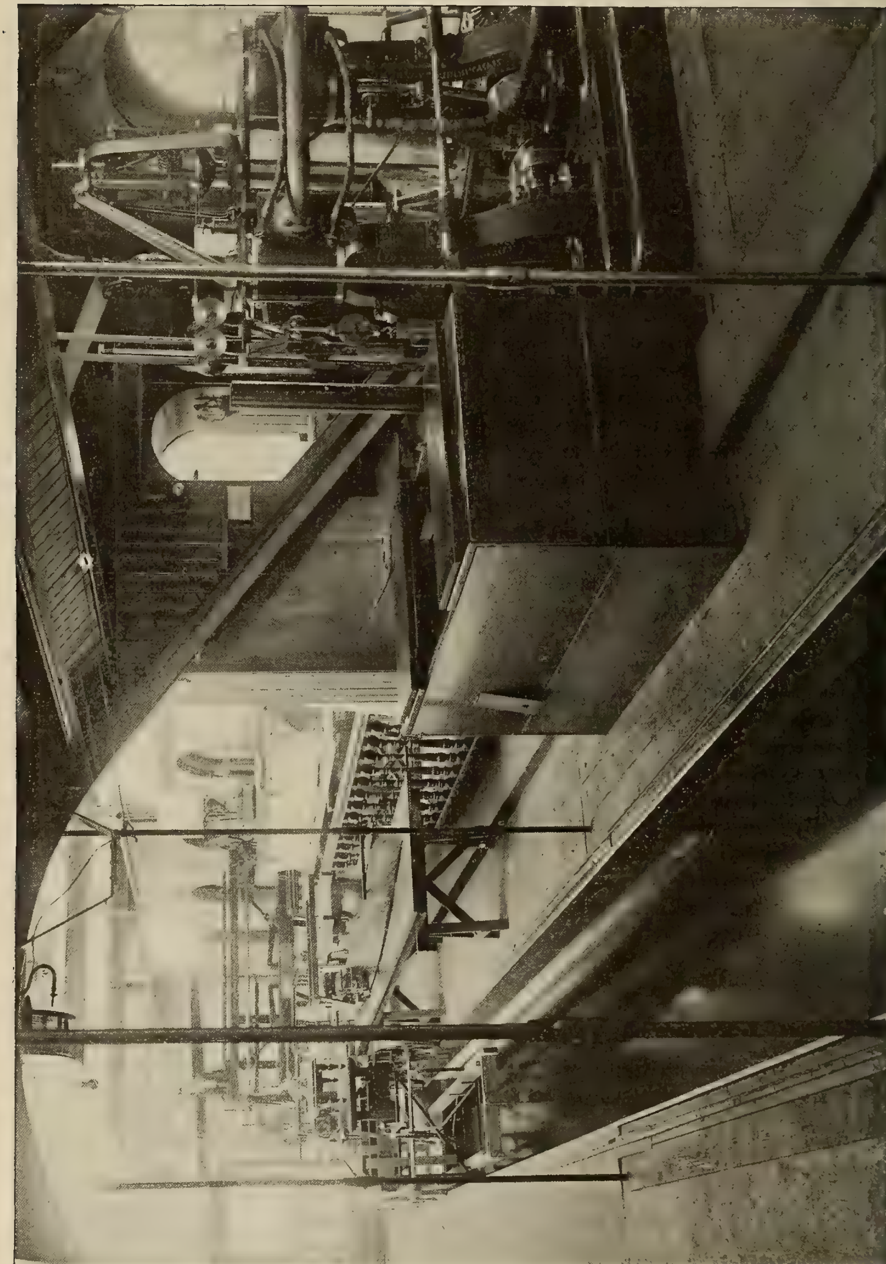


FIG. 14. ANOTHER VIEW OF MESSRS. DENNY & BROS.' EXPERIMENTAL TANK.

shall be of subsequent service, naval architects owe a great deal to the labours of the late William Denny. Not content with getting information regarding power, revolutions, etc., for the maximum speed obtainable by any steamer, as had been the custom before his day; or even with extending that information, so as to include the speed obtained by one-half the expenditure of maximum power, as had been in many cases the Admiralty practice, he organised for his own ships in every case a series of progressive trials which should give all the information desired, from the lowest possible speed to the maximum obtainable; from this information he constructed curves of speed and power, representing the growth of power, revolutions, etc., as necessitated for increasing speed.

Information, thus obtained and arranged, has now come to be universally admitted as having the very highest value and most builders acquire it for new ships; in the first place the curve has a higher value than information for maximum speed alone in that the form of it is a guarantee that no important mistake has been made in the observations. Should this ever be the case there would be an "unfairness" in the curve. Then again, not one speed only is represented, but all speeds up to the maximum, so that if subsequently it is required to predict the power for a similar steamer at less speed this can be done immediately.

Having speed curves, obtained from a large number of actual steamers, of different sizes and of different types, is alone a valuable possession for future use in speed prediction and determination. And since each of these curves can—with due care—be used, in the same way as model results, as applicable to a steamer of any size whatever, as long as it is similar in all respects to the original steamer, their utility is still further enhanced.

Consideration of the foregoing remarks answers, by anticipation, a very obvious question, viz., what information do naval architects rely upon—for matters of speed—who have no tank to experiment in and no tank data to guide them? Where results have been obtained from a steamer for one speed only, it is a very usual thing to express those results in the form of

$$\frac{\text{Speed}^3 \times \text{Displacement}^{2/3}}{\text{Indicated Horse-Power}}$$

the value of the expression being what is known as the Admiralty Constant; the term constant implying, what has long been known not to be true, that the value of expression would not be affected by varying the speed and, therefore, the power of the same ship at the same displacement, or varying the displacement and therefore the power either in the same ship, or by passing from one ship to another somewhat similar in form.

Open to many objections, as the old Admiralty constant certainly is, it still performs a very useful role even in the plotting of results obtained by Mr. Denny's method of progressive trials. A careful discrimination in its use, and avoidance of unduly extending its limits of application are the chief safeguards to apply when, whether by choice or for want of a better method, it is still resorted to.

To a few more matters involving important hydraulic principles I shall now make short references. One is the hydraulic effect of the pressure of wind upon a spread of sails. The effect of this is threefold:—First, the effect chiefly aimed at, viz., the propulsion of the ship through the water, in the line of her keel; second, the propulsion of the ship through the water at right angles to the line of her keel, in other words the leeway; and third, the heeling effect. The movements through the water must be such that the reactions or water resistances caused by them are equal to the wind pressures; the force of the water reaction and of the wind pressure on the sails, both taken at right angles to the line of keel, form a couple, of which the moment is the product of the force involved and the vertical distance between the points of application of wind pressure and water reaction. The angle to which the ship will heel is determined by the condition

that the righting moment must be equal to the moment of wind pressure just mentioned.

Another very important matter is that of rolling at sea. As regards this matter, in comparison with those of which I have hitherto spoken, there is this especial difference; that whereas the theories of the other matters are put into daily practice, the theory of rolling is scarcely beyond the academic state.

Owing to the labours of the late Mr. Froude and Mr. R. E. Froude, in England, M. Emile Bertin, in France, and those who have assisted them, the hydraulic principles involved have been very fully determined, and in the case of some of Her Majesty's ships the extent of rolling at sea has been predicted before the event, but in the merchant service at least this is never attempted, and even in the case of war ships it is the exception and not the rule.

Still, two very important means of diminishing the extent of rolling have been most carefully investigated, and the application of these means in any particular ship is open to every naval architect. The less important of these two means, as being the less certain in its action, is the fitting up of a water chamber on board the ship, so contrived that the action of the water inside the chamber shall as nearly as possible be always in antagonism to the rolling of the ship, tending to bring the ship to port at the time she is starting to roll to starboard, and *vice versa*. The names most closely associated with this means, and its theoretical and practical investigation are Mr. R. E. Froude, Mr. Watts, and Professor Biles. The more important of the means of diminishing the extent of rolling is the application of bilge keels or rolling chocks,—structures attached to the bilges for something like half the length of the ship, and projecting from the skin of the ship to the extent of 8 to 36 inches, according to the size of the ship and the desire to take full advantage of their action. The most recent and most thorough-going investigation of their use and efficiency is that of Sir William White and Mr. R. E. Froude in connection with the bilge keels fitted to H. M. S. *Revenge*.

Experiment in this case seemed to show that the extent of rolling, after fitting the bilge keels, was only about one-third the extent without the bilge keels; this was the case when the ship was not propelled by her machinery; when, on the other hand, she was so propelled, even at a moderate speed, the effect of the bilge keels was even more marked.

Previous experiments with other ships had shown a diminution of rolling due to the fitting of bilge keels of one-half, and for bilge keels of sufficient size this may probably be taken as the least that may be expected. It is to some extent a wonder that, such being the case, ships should ever be built without these valuable adjuncts, and it is probable that, until something better is devised, the future will see an increasing number of ships in which full advantage is taken of a means of giving steadiness so effecttive and at the same time so moderate in cost.

MARINE BOILER FURNACES.

By D. B. Morison, M. Inst. M. E.

THE most important detail in connection with an internally fired cylindrical boiler for marine purposes is the furnace, as it not only represents the most effective heating surface, but, in the event of accidents, the repairs are expensive and usually involve the temporary disablement of the steamer. The earliest form of furnace was square in section, but as soon as steam of a pressure higher than that of the atmosphere began to be used, there was a demand for a design having greater strength to resist collapse; consequently the cylindrical form was chosen and, with modifications, still remains in use.

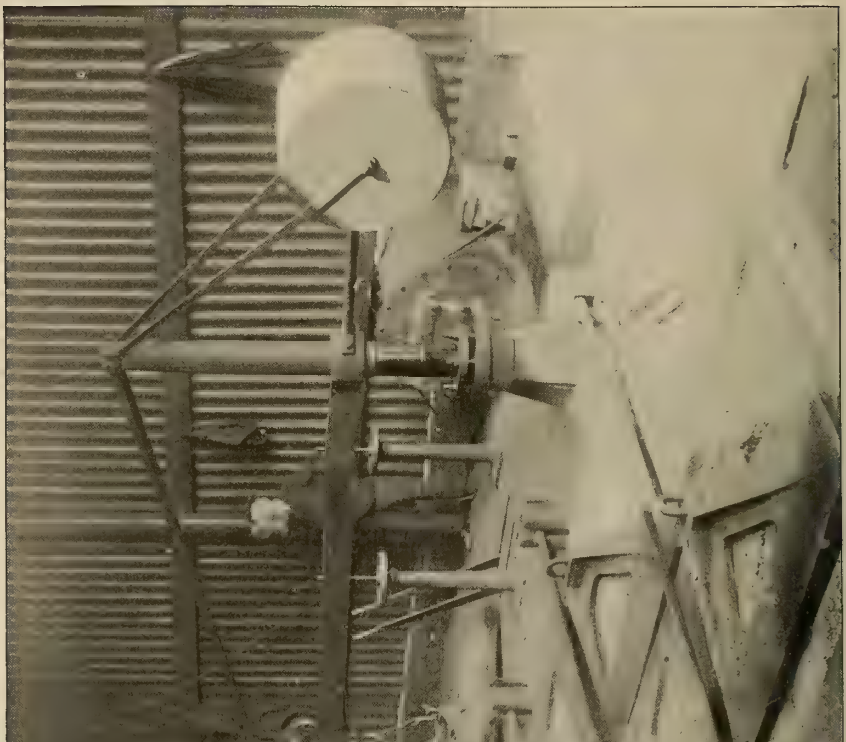
When pressures rose to 100 pounds and upwards, the thickness of the long, plain, cylindrical furnace became excessive, and engineers considered how it was possible to obtain the necessary strength in a more scientific manner than by increasing the thickness of the plate.

Experiments, made by Fairbairn, had shown that the strength of a plain tube under collapsing pressure varied inversely with the length. The first step taken, therefore, to increase its strength was the adding of stiffening rings circumferentially; a better arrangement, known as the "Adamson rings," was, however, ultimately adopted. This design consists of short, plain cylindrical tubes, flanged outwards at the ends, and afterwards rivetted together; but, having so many circumferential joints, they are seldom used for marine boilers.

The great step forward in the history of boiler furnaces is, undoubtedly, due to Mr. Samson Fox, who, in 1878, introduced his now well-known corrugated flue, the strength of which is so much in excess of that of a plain tube that it quickly came into use, and was, for a considerable time, almost universally adopted for high pressure boilers; indeed, it is certain that the rapid adoption of the triple expansion engine was due in a great measure to this invention.

The early manufacture of the corrugated flue was carried on without the aid of machinery, the corrugations being formed from a plain tube by hammering into shape on a corrugated anvil block. Mr. Fox soon realised, however, that machinery was necessary in order to produce a true cylinder, and by unceasing efforts he produced, in 1882, his rolling mill, which is so perfect in design that it has been in constant use ever since and is now employed by the Leeds Forge Company, Limited, of Leeds, England, in the production of the Morison Suspension furnaces.

Corrugated furnaces are made from Siemens-Martin steel ingots which are rolled into plates under ordinary plain rolls. Three sides of the plate are sheared, and on the fourth side the development of the saddle is marked and punched out. The plate is then taken to the bending rolls where it is formed into a tube, after which it is heated by water gas, and lap-welded by hammers of special design. The welding by this process is so effective that in a series of tests, recently made, the tensile strength

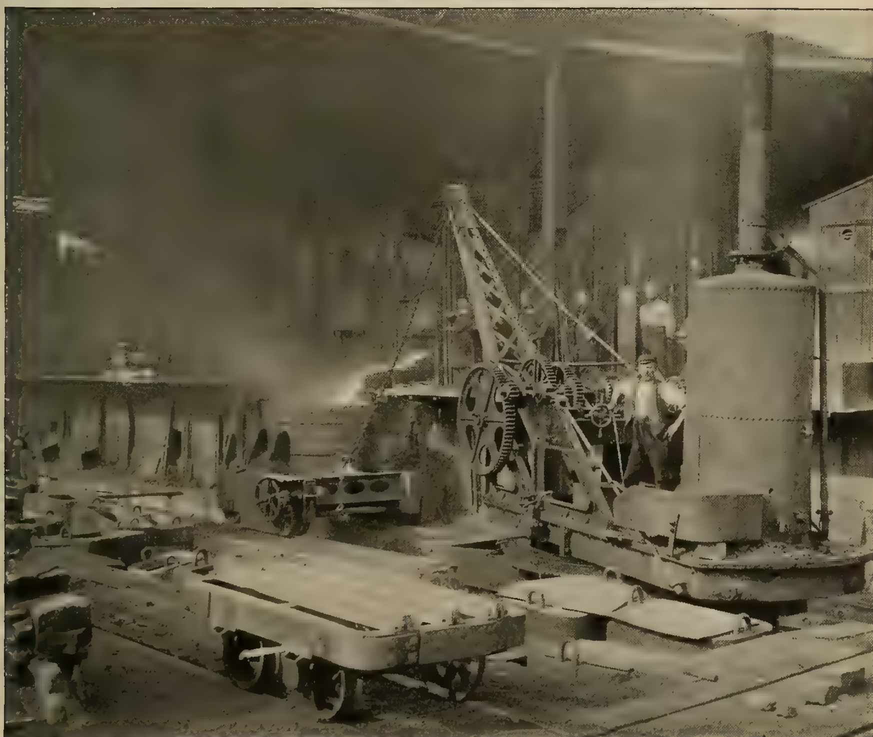


TAKING AN INGOT FROM THE SOAKING PIT.

across the weld was found to be practically the same as that of the original plate.

This welded tube is next heated in a special furnace and placed in the corrugating mill, in which complete corrugations are formed by one revolution; but a few turns are given for finishing, and after being allowed to remain until it is sufficiently cool, it is withdrawn as a perfectly cylindrical, corrugated tube.

John Brown & Co., Limited, of Sheffield, England. This furnace consists of a series of thickened ribs, nine inches between centres, the part between these thickened ribs being of plain cylindrical section. The novelty in this furnace is in the method of manufacture, as it is the first furnace of unequal section and the first furnace not made from an originally plain plate of equal thickness throughout.

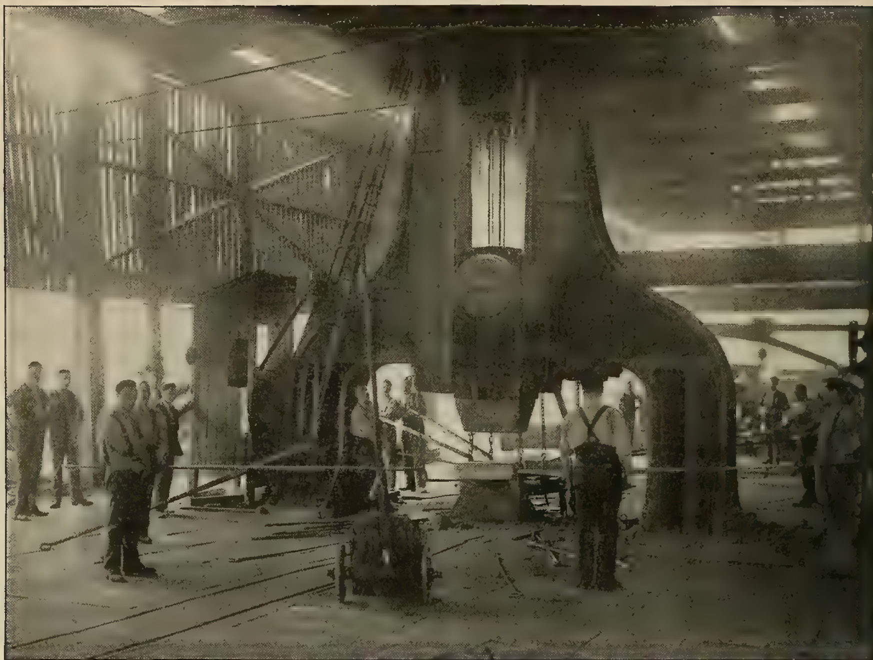


CASTING STEEL INGOTS—THE RAW MATERIAL.

It is then taken to the flanging shop, where the back end is flanged by a hydraulic press, the final process being annealing. Furnaces for the British and other Admiralties are subjected to a pickling process in a solution of hydrochloric acid, which effectually removes all scale and thus enables the most searching examination to be made.

The furnace which was the greatest rival to that of Fox is that known as the Purves ribbed flue, made by Messrs.

The Purves flue is made from a Siemens-Martin steel ingot. Rectangular section slabs, sufficient for two flues, are formed from these ingots under a hammer, the slabs being 7¼ inches thick, and their length being equal approximately to the length of the flue required. Special roughing rolls convert the slab into a ribbed plate, 1¼ inches thick, which is then cut in two by powerful shears, and after reheating, each half is passed through finishing rolls un-



FORGING A STEEL SLAB.

til the final required thickness is obtained.

After being sheared at the edges, the plate is bent into a circular form by a hydraulic press, and the edges are then welded together by the insertion of glut pieces, the plain parts being welded first and the ribs afterwards. The furnace is then heated and converted into a circular tube by a very ingenious hydraulic press and afterwards flanged in the ordinary way, the final process being annealing.

A later design, the Morison Suspension furnace, is an improvement on the Fox corrugated type. It is manufactured by the Leeds Forge Company, Limited, in exactly the same manner, the same processes being employed throughout. This furnace has also had the great advantage of Mr. Fox's extensive experience in furnace design and manufacture, and has been so successful in practice as to practically have rendered the original Fox corrugated form obsolete in the United States and Germany, whilst the demand in England is rapidly ceasing.

The Suspension furnace consists of a series of long curves projecting inwards towards the fire, each curve being approximately a catenary, or the form which a chain assumes when supported between two points. This long suspension curve is the feature of the furnace which has proved so successful in practice, as the tension on the material is more uniformly distributed than in the Fox section with its series of semicircles. There are no inward narrow cavities and consequently there is less liability to local overheating, whilst the long inward curves present a more efficient heat absorbing surface and there is considerable less tendency to alter in form under severe conditions of work.

The apparent practical requirements of a furnace, suitable for high pressure in a modern marine boiler, are:—

The furnace should be of large diameter, to allow of the most complete combustion of the fuel, and to give the highest evaporative efficiency.

The material should be so disposed as to offer the greatest resistance to col-

lapse without extreme rigidity in a longitudinal direction.

The strength of the flue should be uniform throughout its length, so as to prevent local sagging.

The material should be of equal thickness throughout, so that expansion may be uniform, and not unequal and local.

The formation should be such that the stresses resulting from extreme variation of temperature should be distributed throughout the length of the furnace and not concentrated in any point, so as to prevent ripping or extended fracture.

There should be no narrow cavities or recesses towards the fire in which deposit may accumulate and result in the overheating or burning of the material.

The strengthening projections should be outwards, or towards the water space, and thus protected from the fire.

The furnace should be of such formation as to be easily scaled, cleaned, repaired, or replaced.

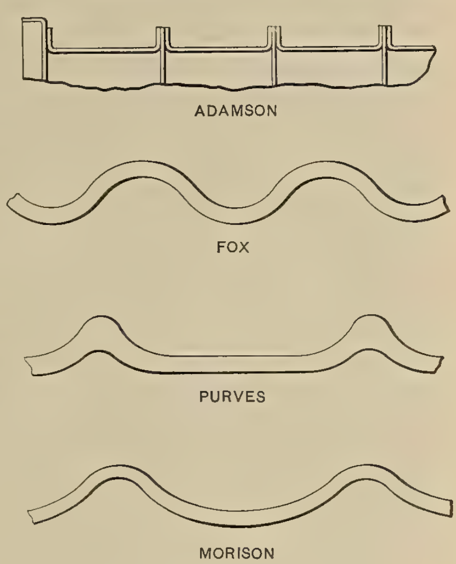
The material should be of the best quality and suitable for the comparatively rough treatment of the boiler shop, as well as the alternate and repeated reheating and cooling of the furnace when in use.

The aim of the designer should, therefore, be to so dispose of the material that it is in the best form to resist collapsing pressure, thus enabling a mild steel to be used, it being obviously of greater practical advantage to depend on design for strength than to obtain it by using hard, brittle steel.

Before proceeding to consider how the various designs fulfill these apparent requirements, it should be noted that the present standard pressure in a marine boiler is 180 pounds per square inch, with a tendency to increase that pressure; also, that a furnace of large diameter, with a short grate, is much more efficient than a small diameter with a long grate, for two reasons, one being that the combustion is far more complete in the larger furnace, and the other (the practical reason) that an average fireman is able to fire a short grate better than a long one.

These considerations alone seriously detract from the value of ordinary plain furnaces, but the fact that the first cost is less than that of any others is, no doubt, the reason why they are still used, although, whatever may be the advantage to the builder of the boiler, there is no question as to the disadvantage to the shipowner. The most essential feature of an efficient furnace, from an evaporative point of view, is that it shall be of large diameter, and this, with modern pressures, is impossible with plain furnaces.

The material of a furnace is subjected



SECTIONS OF FURNACES.

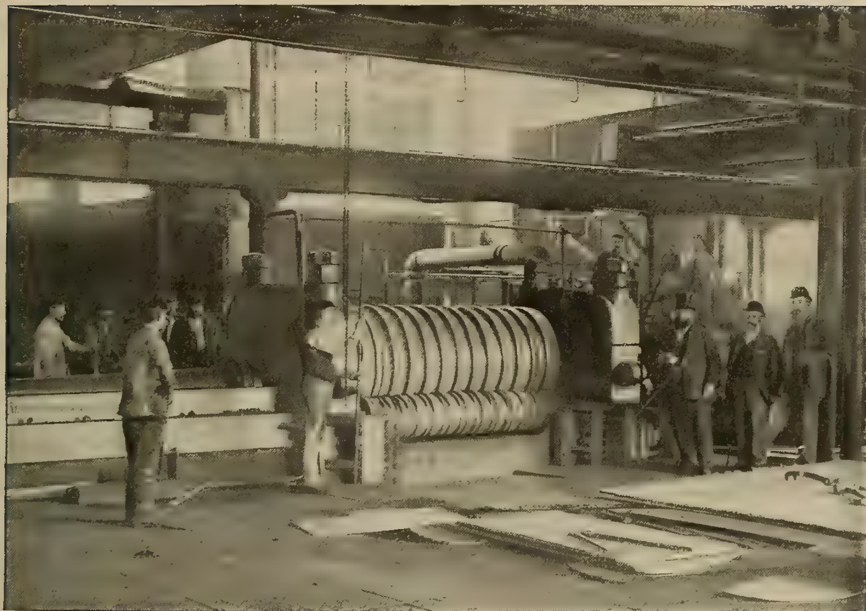
to greater variations of temperature than any other part of the boiler. These variations are incessant, and depend on the condition of the fires, opening and shutting of doors, and cleaning of fires, and result in continual expansion and contraction, producing definite mechanical movement. If the design of the furnace is such that it cannot readily adapt itself to these movements, the material becomes distressed and ultimately cracks, or such stresses are produced on the boiler that leakage follows. The Adamson design is a considerable advance upon the plain furnace, as it is

less rigid in a longitudinal direction and is stronger to resist collapse.

The Fox corrugated furnace, at the time of its introduction, was the strongest ever made, whilst the nature of its formation rendered it specially suitable for accommodating itself to the stresses resulting from variations of temperature, and as it is of uniform thickness and design, these stresses are distributed uniformly throughout the length of the furnace. This uniform distribution is a most important feature, since, if the stresses are localised, accidents must ultimately result. Theoretically, the Fox furnace approaches perfection; practically, however, it has defects, the chief one of which is a tendency for deposit to accumulate in the narrow cavities formed by the inner corrugations, and as the temperature of the material forming these cavities is, by its position, higher than at any other part, overheating is liable to result and cause a decrease of safety factor. If overheating is of frequent occurrence, the material becomes so distressed that small longitudinal cracks ultimately develop.

The extreme longitudinal elasticity has also been proved, in practice, to be unnecessarily great, and detracts from the strength to resist deflection or deformation. These practical defects of the Fox furnace, being generally recognised by engineers, was, undoubtedly, the chief cause of the adoption of the Purves design, in which not only are the supporting rings in the water space, and thus removed from the direct action of the fire, but there are no cavities for the unequal accumulation of scale and

WELDING A PLAIN TUBE BEFORE CORRUGATING.



ROLLING A MORISON SUSPENSION FURNACE IN A FOX CORRUGATING MILL.

no greater expense is incurred in scaling than with plain furnaces.

These advantages are obtained, however, at the sacrifice of others, as, all conditions being similar, the Purves design is not so strong as the Fox to resist collapse, whilst its unequal section and extreme longitudinal rigidity localise the stresses resulting from variations of temperature, an evidence of which is the occasional development of circumferential ripping, or extended fracture at the base of the ribs.

It was the writer's practical experience with corrugated and ribbed furnaces which suggested the design of the Suspension furnace, the object being to retain those features in the Fox and Purves designs which had been proved to be necessary for practical success, and to reject those features in each which practice had proved to be bad.

A frequently suggested arrangement is the simple reversal of the suspension design, thus making the long suspension curve into an arch, the claim being that it might be stronger to resist collapse, but, even if such were the case, a furnace should be judged, not from its capacity to withstand a high cold water test pressure, but rather from what experience has shown to be necessary for success in actual working under steam, and very little reflection will show that the flame, striking on the inwardly projecting narrow cavities, must result in a tendency to overheating and ultimate cracking.

A feature often claimed for the Fox design is additional area of heating surface, but when it is remembered that the current of heated gases impinges on the inward corrugations, whilst the recesses formed by the outward corrugations are filled with gases of a lower temperature which are comparatively stagnant, the efficiency of this additional surface is, in the writer's opinion, often overestimated. The same argument applies to any arched surface, and there is no doubt that the evaporative efficiency of the material forming the arches is lessened by reason of its position and formation.

Severe, but useful, lessons often result from furnace accidents, useful in the sense that practical experience has been gained, which, combined with a

FINISHING TO TEMPLATE.

true appreciation of scientific principles, forms a sound basis for future guidance in dealing with this most important detail in marine engineering.

The furnace manufacture for the mercantile marine of England is under the direction of the Board of Trade, Lloyd's Registry and other Surveys, as not only do these authorities determine the limits of the tensile strength of the steel to be used, but, by formulating rules, they control the weight, and consequently the commercial value, of every type of furnace used in marine boilers. It will be evident, therefore, that very accurate experiments are necessary to obtain reliable data. These experiments are carried out by the Board of Trade, witnessed by representatives of the other surveys, and are of the most elaborate, stringent, and exhaustive character. Six furnaces are required, about 36 inches in diameter, 6 feet 6 inches long and from 5-16 to 9-16 inch in thickness; each furnace is rivetted in a very heavy steel chamber and subjected to hydraulic pressure until collapse takes place. From these pressures the collapsing co-efficients are obtained by multiplying the diameter of the furnace in inches by the pressure in pounds at which collapse took place, and dividing by the mean thickness in inches, thus,

$$\frac{P \times D}{T} = \text{collapsing co-efficient.}$$

This co-efficient, divided by the factor of safety, gives the official constant.

The diagram on page 377 shows the strength co-efficients obtained from official tests conducted by the Board of Trade on all the principal furnaces which have been used during the last twenty years. There is no fixed standard factor of safety, as may be found by dividing the co-efficients on the diagram by the various official constants. For example, both the Morison and the Fox designs have the same Board of Trade official constant, viz., 14,000, and yet the test value of the former is much greater than that of the latter. One apparent reason for these varying safety factors is that the rapid increase of steam pressures has resulted in increased temperatures of the material of which the furnace is

HYDRAULICALLY FLANGING A FURNACE.

THE LAST BLOWS.

made, and therefore it is desirable to increase the factor of safety under cold water test to compensate for the reduction in the range between the temperature of the plate when under steam pressure and the temperature at which the tensile strength of steel rapidly decreases.

It is very unfortunate, however, that in view of the extreme accuracy of these tests the various surveys cannot agree on a standard safety factor as well as on a standard rule, as users who have not had an opportunity of analysing these results for themselves, are compelled to follow the various rules blindly, and can only assume that the safety factor is equal for all types of furnaces. This, however, is not the case. For example, the Board of Trade rule for Suspension furnaces is

$$\frac{14{,}000 \times T}{D} = \text{working pressure,}$$

where $T =$ thickness in inches, and D = least outside diameter in inches.

Lloyds rule is:—

$$\frac{1259 \times (T - 2)}{D} = \text{working pressure,}$$

Where $T =$ thickness in sixteenths of an inch, and $D =$ greatest diameter in inches.

This $(T - 2)$ means that 2-16 are deducted from the actual thickness of the furnace plate to allow for possible ultimate corrosion, the fact that excessive corrosion is now the exception, rather than the rule, being lost sight of; but one of its worst features is that it gives a premium to thick furnaces.

For example, take a Purves furnace 3 feet inside diameter and 7-16 inch thick. The working pressure allowed by the Board of Trade is 166 pounds per square inch, and by Lloyd's 157.5 pounds, or a difference of 8.8 pounds in favour of the Board of Trade. Now take

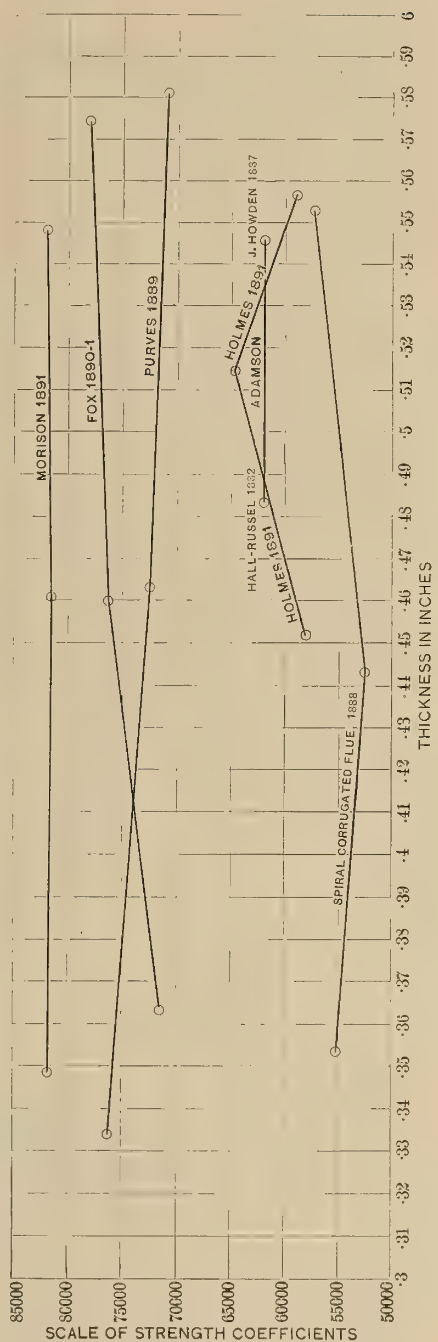
the same furnace, ⅝-inch thick. The Board of Trade pressure is 235 pounds and Lloyd's 249 pounds, or a difference of 14 pounds in favour of Lloyd's, or a total difference of 22.8 pounds resulting from the application of Lloyd's rule.

In a Purves design especially, it is seen, by the diagram on this page, that the thicker furnace is relatively the weaker under cold water test, and this would be intensified under steam, so that the wisdom of the formula in this particular case seems very doubtful; but it is only fair to state that the rule is an old one and, no doubt, will soon be revised.*

Each survey has also a limit thickness, that of the Board of Trade being ⅝-inch, and Lloyd's ¾-inch. The latter probably approaches a thickness beyond which it is undesirable to go, as with modern pressures the temperature of the steam is from 360 to 400 degrees Fahr., and, consequently, when it is remembered that at 700 degrees the tensile strength of the material commences to rapidly decline, the margin is certainly not any too great.

In view of the success of furnaces up to ¾-inch in thickness, it would seem desirable that the Board of Trade should increase their limit thickness to say 11-16-inch, so as to allow users to obtain the advantages of high pressures and comparatively large diameters. Whatever the limit thickness may be, there should be allowed a rolling margin of 1-32-inch as furnace manufacturers usually roll their plates slightly thicker than actually required, and thus increase the factor of safety on the furnace; but at the limit thickness, if no rolling margin is allowed, it follows that the safety factor is at a minimum.

The suitability of material in the manufacture of furnaces is the first essential to practical success. On the introduction of the Fox furnace in 1882 the manufacturers considered that steel of a low tensile strength, with high elongation, was the best for the varied requirements of a furnace, and therefore adopted a



RESULTS OF BOARD OF TEADE OFFICIAL TESTS ON BOILER FURNACES.

* This question is very humourously dealt with by Mr. Cruickshanks, the Engineer-in-chief of the New South Wales Marine Board in his able treatise on "Boiler Construction."

range of tensile strength from 23 to 26 tons per square inch. The Board of Trade and Lloyd's Registry, however, consider 26 to 30 tons as being the most suitable, and allow a higher official constant than for the lower range. A few

BOARD OF TRADE METHOD OF TESTING FURNACES TO DESTRUCTION.

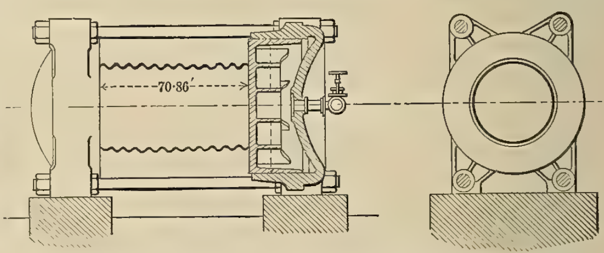
years ago, when competition in furnace manufacture commenced, a large number of furnaces were made of steel approaching 30 tons tensile strength. Accidents from cracking quickly followed, and now experience has clearly proved that from 26 to 28 tons is a range beyond which it is not prudent to go.

The influence of temperature on the behaviour of mild steel under tension was ascertained by a splendid series of experiments, made by the United States Navy Department in 1888. Briefly, the results obtained are that the tensile strength of all steel varies between zero and 200 degrees Fahr.; the maximum strength is between 400 degrees and 600 degrees, and beyond 600 degrees the tensile strength decreases rapidly. Although the ultimate tensile strength increases from 200 degrees to 600 degrees, the elastic limit steadily decreases from zero upwards, and steel, having an elastic limit of 35,000 pounds per square inch at zero, has its elastic limit reduced to 20,000 pounds per square inch at 600 degrees Fahr.

Another point is that the higher carbon steels reach a temperature of maximum strength more abruptly and retain their highest strength over a less range of temperature than steels having a low percentage of carbon. In furnaces from ½-inch to ¾-inch thick, under 200 pounds steam pressure, the temperature of the plate, when clean, approaches a temperature of maximum tensile strength; therefore, the use of hard, brittle steel is rendered dangerous, especially with furnaces of very rigid design.

The exhaustive experiments of Herr Otto Knaudt, of the firm of Schultz, Knaudt & Co., of Essen, Germany, on the longitudinal elasticity of furnaces form a most valuable addition to furnace literature. The question is a most important one in furnace design, as, whilst excessive longitudinal elasticity detracts from the strength to resist deformation, extreme rigidity is conducive to fracture. The experimental apparatus of Herr Knaudt consisted of a hydraulic press in which the furnace to be tested was placed horizontally between the body of the press and a hydraulic ram, these two representing the ends of a boiler.

The load was applied longitudinally, in increments of 15 pounds, each increment on the pump representing 20 tons



HERR OTTO KNAUDT'S APPARATUS FOR ASCERTAINING THE LONGITUDINAL ELASTICITY OF FURNACES.

on the ram. On the completion of each increment, the shortening of the furnace was measured, the pressure taken off, and the length again measured in order to ascertain the amount of permanent set, if any.

Of the furnaces experimented on, four were of the ordinary Fox corrugated type, 37 inches inside diameter, the thickness of each being 0.393, 0.46, 0.472 and 0.3535 inches respectively; one Adamson ring furnace 0.551 and

one Purves ribbed furnace 0.472 inches thick. For a comparison of results, take a uniform pressure of 100 tons, applied at the ends of the furnace. In the Fox furnaces the compressions per 36 inches in length were 0.134 inches, 0.112 inches, 0.093 inches and 0.075 inches; in the Adamson furnace 0.021 inches, and in the Purves ribbed furnace 0.0071 inches. In other words, the pressures required to shorten these furnaces 1-32 inch per 36 inches in length would be, for the four Fox furnaces, 19.2, 24.7, 30.7 and 41.8 tons respectively; for the Adamson, 145.2 tons; whilst to compress the Purves ribbed design would take 300 tons.

Recent experiments have shown that the Morison section has slightly less longitudinal elasticity than the Fox, but experience has proved that it has a greater tendency to preserve its original circular form under work, due, no doubt, to the uniform stiffening effect of the ridges, which give a little less elasticity and correct, to an appreciable extent, the disposition to sag under severe conditions of work.

The most complete survey on the manufacture of furnaces is that of the British Admiralty, but for the mercantile marine of England the most careful and reliable is that of Lloyd's Registry. Each plate is examined by the surveyor, who stamps certain portions from which tests are made for tensile strength, elongation and bending; if these tests are satisfactory, the plate is passed and the manufacture of the furnace is proceeded with. On the completion of each furnace, and before it leaves the works of the manufacturer, careful measurements are taken throughout its length in order to ascertain that the deviation from a true cylinder is not excessive. The flanged corners are examined for the amount of radius and also for thickness; a template is applied and compared with the drawing, and only after this exhaustive examination, is the furnace stamped officially by Lloyd's surveyor, and allowed to leave the works. The Board of Trade, Bureau Veritas, etc., simply test the material and make no examination whatever of the furnace at the works of the manufacturer.

Modern pressures demand the utmost care, and it would seem a great advantage to users, and would certainly be in the interests of safety, if an official survey took place at the works of the furnace manufacturer and each furnace received the official stamp on completion. The manufacture would, undoubtedly, be improved thereby, liability to errors lessened, and the safety factor of the most important detail in a cylindrical boiler increased.

STEAMERS FOR SHALLOW RIVERS.

By John I. Thornycroft, F. R. S.

ON THE NILE AT CAIRO.

SHALLOW, rapid rivers often provide the only means of access to new countries. To utilise these waterways quick steamers are necessary, but limited draught of water and length of hull tend to make the attainment of sufficient speed very difficult, and much skill has been used in adapting the paddle wheel to propel vessels of steel of special construction to secure lightness with the greatest possible strength.

The results obtained from this construction are, however, impaired by the great weight of the propelling machinery which cannot be avoided when slow running engines are employed, while the screw, in its ordinary form, is not adapted to work with the limited immersion available. But fast-running engines can be successfully employed in vessels of very shallow draught by adapting the stern lines and the form of the propeller to the conditions involved.

Taking first the form of the stern best adapted to favour the efficient action of the screw propeller, when immersion is limited, it has been found that air must be prevented from finding a way into the region of low pressure, forward of the screw, and this is easily done by so forming the stern that the water surface in the neighbourhood of the propeller, and in front of it, is effectively covered by the surface of the hull. The importance of this is evident from the fact that the efficiency of the propeller is re-

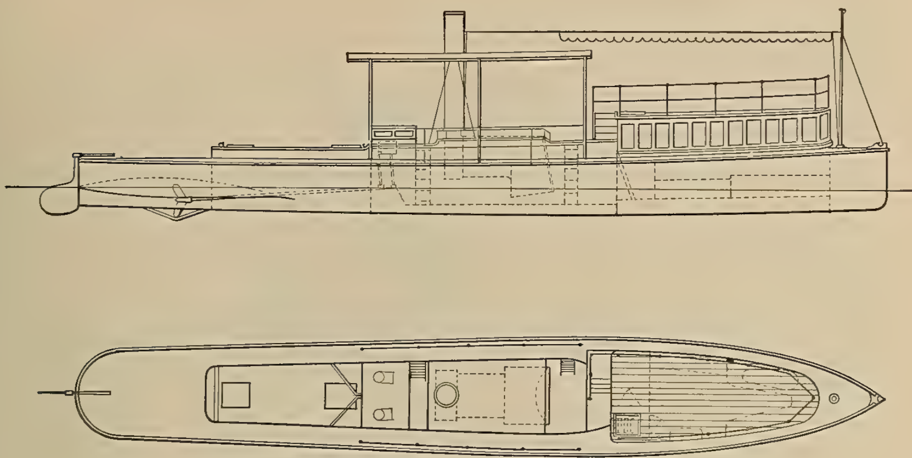


FIG. I. A TURBINE-PROPELLER TUG FOR THE RIVER NILE.

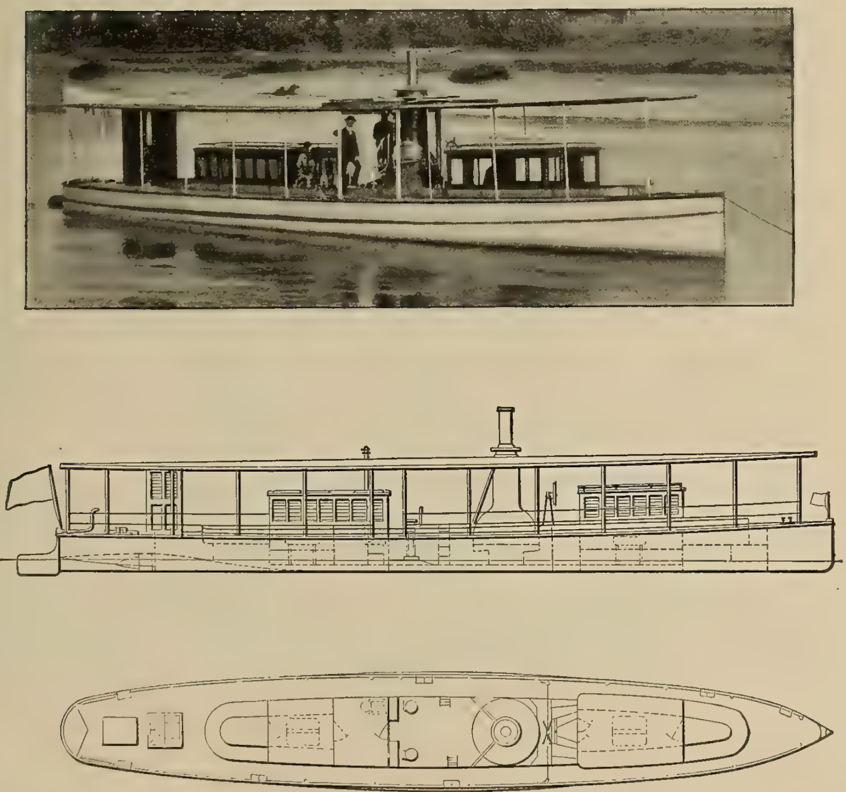
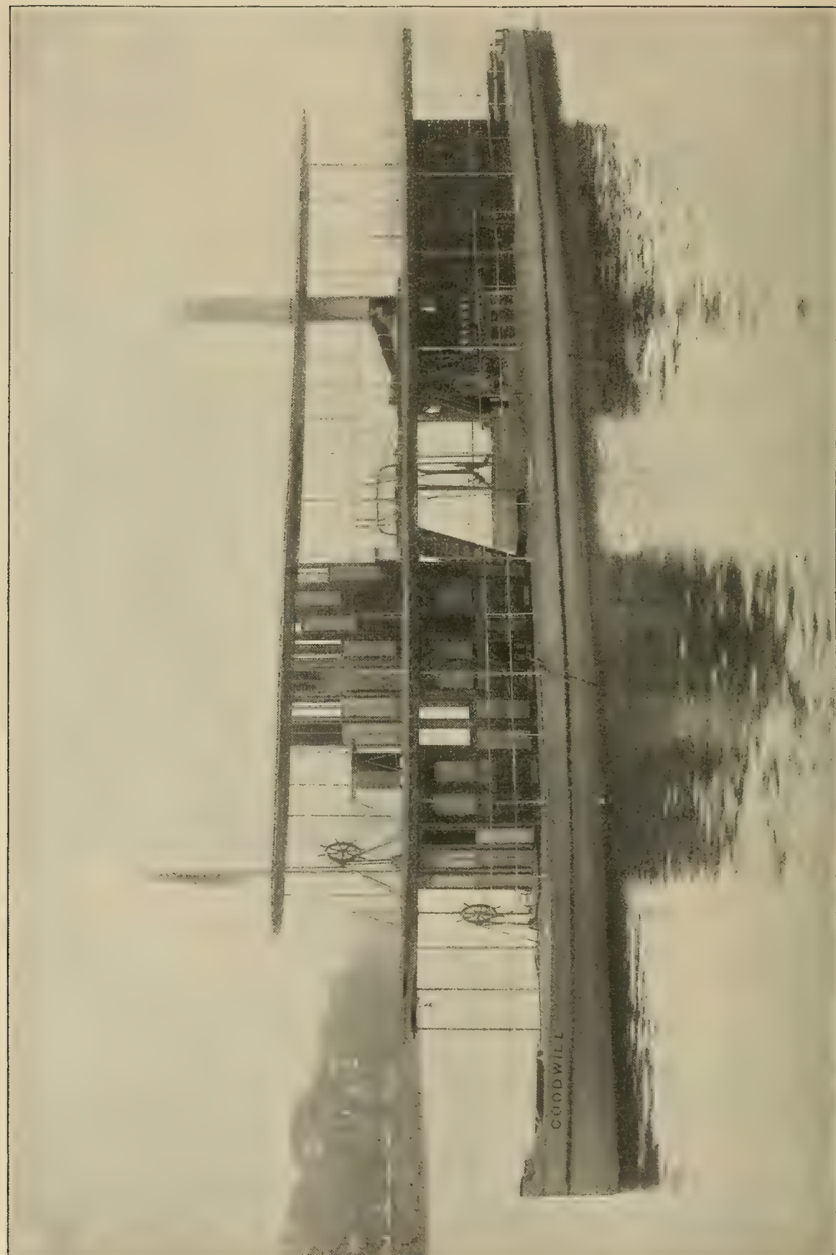


FIG 2. THE "PEACE" ON THE UPPER CONGO, AFRICA.



THE "GOODWILL," DESIGNED AND BUILT FOR UPPER CONGO SERVICE, BY MESSRS. JOHN I. THORNYCROFT & CO., LONDON.

duced by about 30 per cent. when air finds its way into the screw race.

A form of stern protecting the propeller from air has been used for a considerable time in canal tugs. The *Dunderburg*, an ironclad, built in America and which was bought by the French Government in 1867, had stern lines finishing in a plane at the water surface. Very remarkable results were obtained with this vessel. In adapting this principle to shallow draught, however, it is possible to go much further than has been done in the canal tugs and the *Dunderburg*, because the atmospheric pressure is capable of supporting water in a space extending far above the external water surface so long as air cannot enter, and at the same time the supply of water to the propeller will not be impaired except at very high speed.

Mr. Edmund Froude has shown that the acceleration of the propelling stream is half done before arriving at the plane of the screw's disc, even if the loss of pressure due to rotation be neglected; but it is only when a very high speed is attained that the continuity of the stream seems to break and the efficiency of a propeller suddenly falls without air finding a passage to cause the trouble.

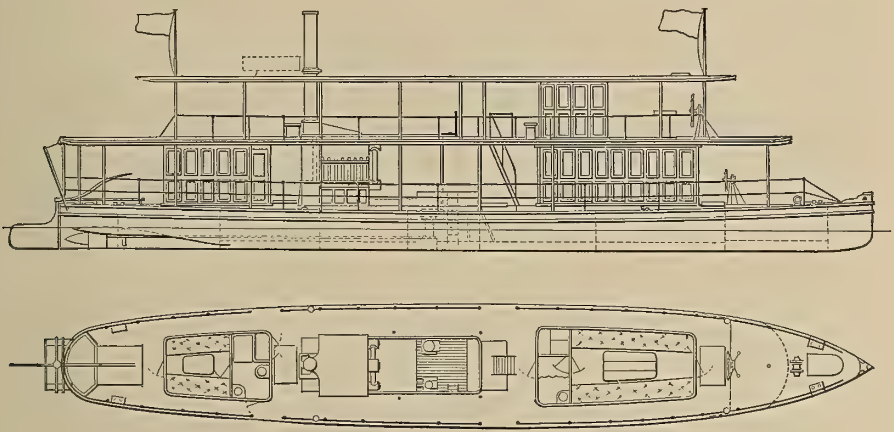


FIG. 3. THE CONGO STEAMER "GOODWILL."

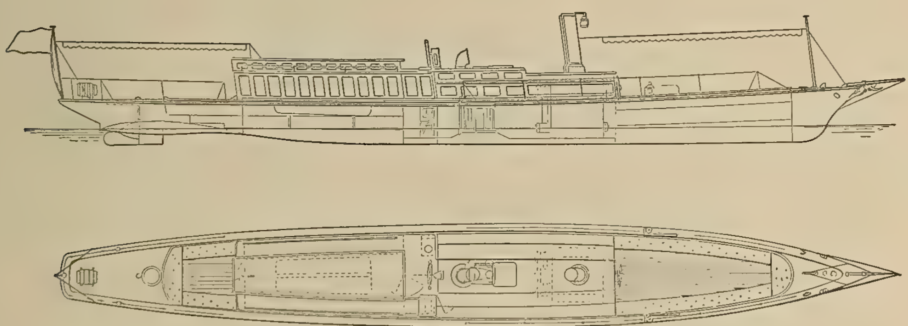


FIG. 4. THE "AURORA," A THAMES LAUNCH.

An example of a shallow-draught tug, in which the principle has been adopted of raising part of the propelling stream above the water line, in order to completely immerse ordinary propellers of a diameter greater than the draught of the vessel, is afforded by the design

THE PATROL STEAMER "ERNEST," BUILT FOR SERVICE ON THE RIVER NILE FOR THE RELIEF OF KARTOUM, BY MESSRS. JOHN I. THORNYCROFT & CO., LONDON.

shown in Fig. 1, which represents a boat built for the Nile.

In this, part of the propelling stream is carried above the external water surface, forming a load to be carried by the boat, and two 3-foot screws are completely immersed, although the draught an hour was obtained with 72 I. H. P., and 16½ miles with 104 I. H. P.

The boiler employed in this vessel was of the locomotive type and consequently was much heavier than would have been necessary for the same work if a water tube design had been adopted.

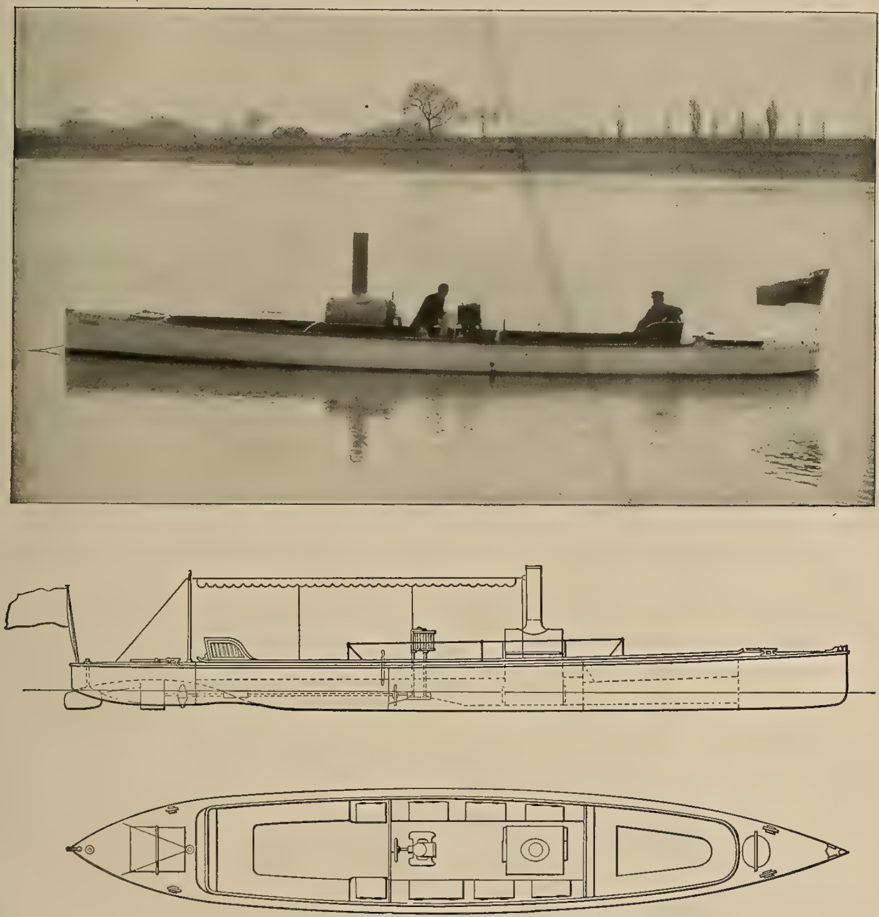


FIG. 5. THE SHALLOW-DRAUGHT RIVER LAUNCH "BOADICEA."

of water of the boat is only two and one-half feet. From experiments made on the Thames, it was estimated that the boat would tow an Egyptian dahabeah of forty-five tons at a speed of 9 miles an hour. The result of a trial on the Nile was a mean speed of 9.22 miles, towing an iron dahabeah of forty-eight tons, with and against the current. When not towing, a speed of 14.7 miles

In the year 1881 the *Peace* was built for the Baptist mission for use on the Upper Congo in Africa, where a vessel of very light draught and considerable speed was desired. All the parts of the entire vessel having to be carried inland a long distance by men, led to a water tube boiler being constructed for this boat, as it enabled a considerable saving in weight.

This boiler was completely put together by natives, and steam was raised on the third day after re-erection was begun. It worked for six years on the steamer, and, afterwards, for a number of years, furnished power for a saw-mill at the station.

The *Peace* was designed to carry four persons and the necessary fuel and stores, with a draught of water of one foot. It is not, therefore, surprising that Mr. Stanley should have failed to realise a high speed from this boat when he had loaded it with 135 people.

It will be seen from Fig. 2 that in this vessel the draught of water is much less than could have been attempted if ordinary screws had been employed. The boat is propelled by two turbine propellers, which, for about a quarter of their diameter, are above the water line, the stern being hooded as in the vessel previously described. A trial was made on the Thames, when a speed of 12 miles was attained at the intended draught of water,—twelve inches. The boat was shipped, packed in a great number of very small loads for land carriage, and was re-erected by natives under the direction of the Rev. George Grenfell, one of the missionaries, who found the shallow draught of this vessel most convenient when exploring some of the tributaries of the Upper Congo, which were previously unknown.

This boat was at one time forcibly requisitioned by the Congo Free State, being the only craft on the river which had a sufficiently light draught for their purpose, and in order to avoid the possibility of being again left without a vessel with which to communicate with the different stations of the Baptist mission on the Congo, a second steamer, the *Goodwill*, was ordered. This vessel has also two turbine propellers and compound engines, the high pressure cylinder working one propeller, while the low pressure cylinder works the other. The *Goodwill* has also a water-tube boiler of the *Speedy* type, and was built in 1891. (Fig. 3.)

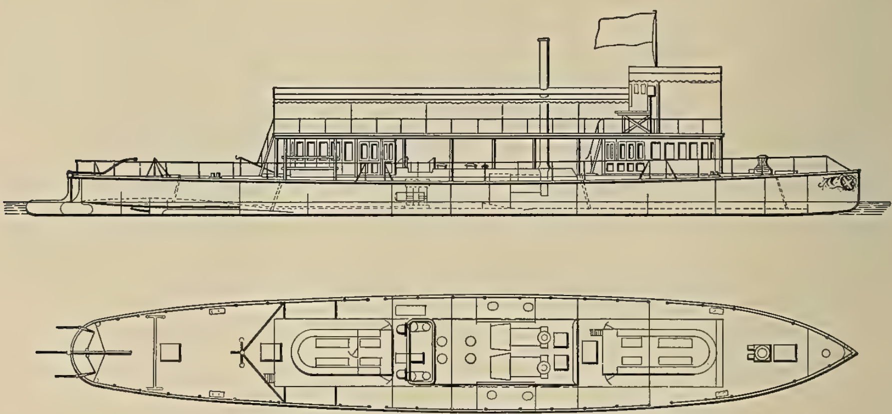


FIG. 6. PLAN AND ELEVATION OF THE PATROL STEAMER "ERNEST."

The draught of water and the carrying capacity of this vessel are greater than those of the *Peace*, as it was not found necessary to so far restrict the draught of water for the part of the Congo where this vessel had to work. The *Goodwill* is 84 feet long, 13 feet beam and draws 2 feet 2 inches when laden with cargo of thirteen tons weight. There are three cabins, giving sleeping accommodations for eight persons.

Fig. 4 represents the *Aurora*, a launch of shallow draught, built for use on the Thames. It is fitted with one turbine propeller only, has compound condensing engines and a water-tube boiler, and has attained a speed of 15 miles. Experiments were made with this vessel by putting heavy weights in

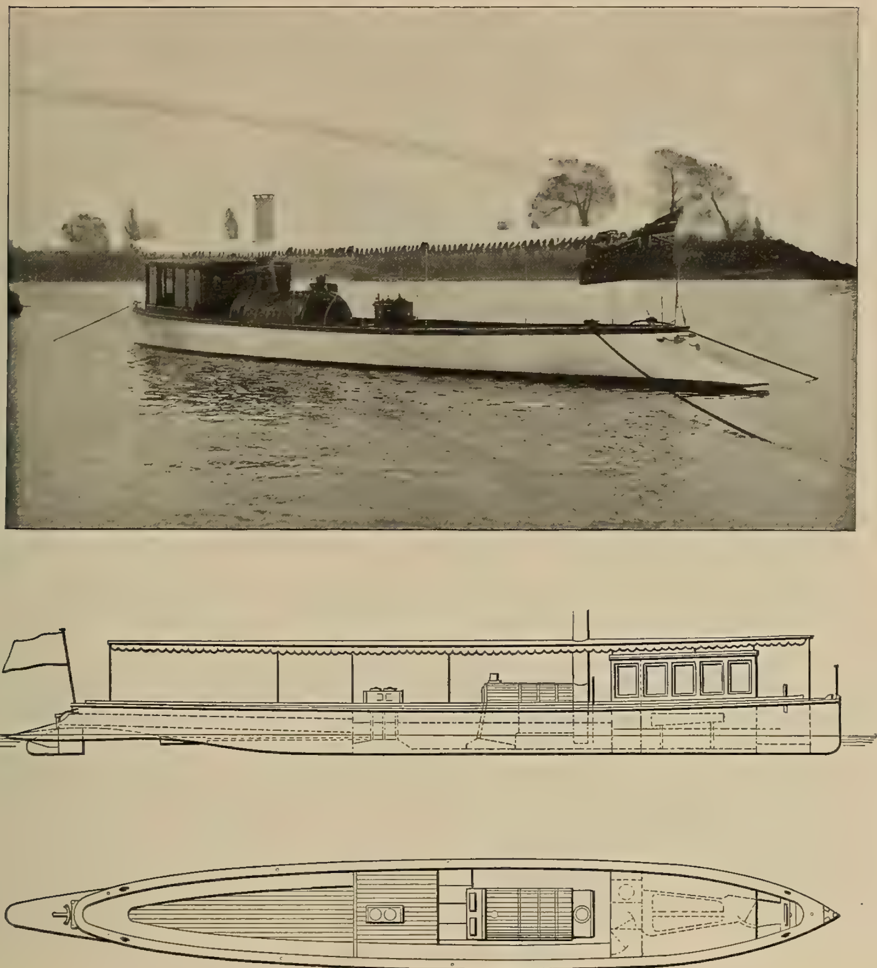


FIG. 7. A LAUNCH FOR NILE SERVICE.

the extreme bow, so as to raise the stern much above its intended position. By this means the draught of water at the propeller was reduced to about ten inches, and the back of the tunnel was so lifted as to be quite clear of the water. Notwithstanding this unfavourable position, the propeller, when turned very rapidly, drove out all the air and propelled the boat at a high rate of speed. The speed of the engines could then be reduced until the boat was moving only slowly, without breaking the column ot water from the propeller.

This experiment is interesting as showing how large a part of the propeller may be above water so long as air cannot mingle with the stream of water going to the propeller, and has led to building some vessels for towing with single turbine propellers, their axes nearly at the water line. An incidental advantage of this construction is that it gives great facilities for inspecting the propeller. A door situated over the propeller, when opened, allows the water to fall to the level of its external surface and exposes to view half the propeller above water.

Fig. 5 represents the *Boadicea*, a river boat of very shallow draught,—only ten inches,—and of a speed of 13.8

miles an hour, which, if the small dimensions of the boat are considered, is very high. This is fitted with one turbine propeller, 16 inches in diameter, driven by a single high-pressure engine, supplied with steam from a water tube boiler. The shallow draught of this boat enables it to use its full power in very shallow water, and by attaining a speed at which the ordinary wave formation can no longer keep pace with it, it glides over the water in the same manner as the light canal passenger boats, described by Mr. Scott Russell, did when towed by horses on the towing path, faster than the wave in the shallow canal could advance, and under these circumstances the resistance to motion was reduced.

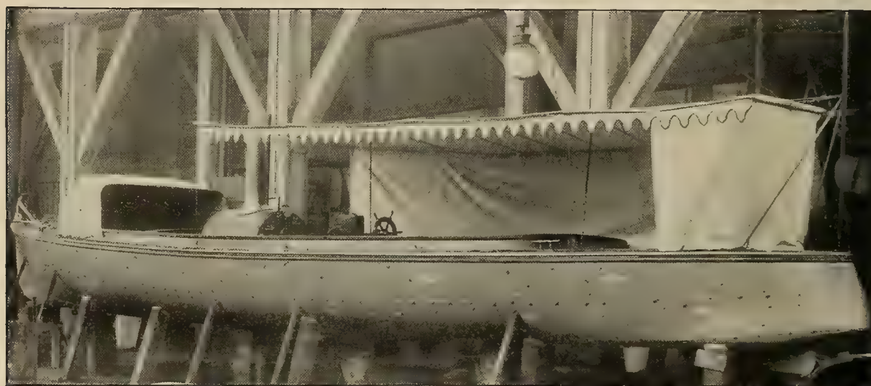


FIG. 8. ANOTHER THORNYCROFT LAUNCH, FOR SERVICE ON LAKE NYANZA, AFRICA.

This launch was recently purchased by a French trading company for use on a very shallow river in Madagascar.

In India the importance of the rivers as a means of communication, is shown by the fact that more than 400,000 laden boats were registered at some of the river stations in Bengal in the year 1877-8. Where the railways have been able to compete with the steam service on the rivers, the steamers are said to have lost the field, but possibly the same influence which killed the canal service in England may have crippled the water service in India.

Many of the canals in England were bought up by the railway companies in order to avoid the kind of competition which might arise from the canal companies carrying goods at a lower rate than was possible for the railway companies. If the railway companies found this course desirable where the canals had to be made and kept in order, it would seem that where there is a large river, like the Ganges, or Brahmaputra, navigable all the year round, and requiring no repair, water carriage should hold its own, and suitable steam vessels gradually take the place of the native craft which are now so numerous.

In Egypt the Nile, in its natural state, affords even now the only road of importance to the Upper Nile valley. The proposed engineering works at Assouan will, by the enormous storage of water afforded, render the depth of the current below the first cataract more uniform throughout the year; while the locks, by making this cataract always passable, will give uninterrupted communication as far as the second cataract, thus extending the navigable river about 200 miles, or a total of 950 miles from the Mediterranean at low Nile.

In the year 1885 five boats were built, of the design illustrated by Fig. 6, for service on the Nile for the relief of Kartoum, and one of these tried in October, attained a mean speed of 15.1 knots, the draught of water being 1 foot 4½ inches forward and 1 foot 10½ inches aft. The boats were fitted with three rudders which, being in the race of

FIG. 9. THE PASSENGER STEAMER "BIJOLI" AT CALCUTTA.

water from the propellers, gave excellent control in steering, and it is believed that these boats would have steered well through the rapids if they had been called upon to do so. It was, however, unfortunate that they were never called upon to do the work for which they were designed, as, although completed in a very short time from the date of the order, Kartoum had fallen before they left England. Three of the boats were afterwards sent to Burmah, where they have done useful service.

These boats are 140 feet long by 21 feet beam and are built of steel. They have ¼-inch musket-proof plating alongside the engines and boiler room and are divided by transverse and longitudinal bulkheads between the engines and boiler rooms, so that each of the two turbine propellers has machinery in a separate water tight compartment.

The conning towers are steel plated and there are also deck houses fore and aft, which are steel plated and loopholed for the use of musketry, and each boat is fitted with a powerful steam winch on the deck forward for warping the boat with a steel wire rope if necessary. The machinery consists of two

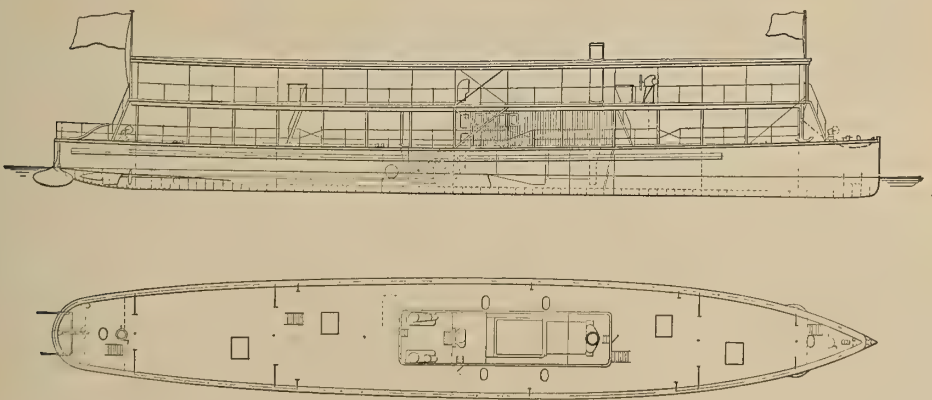


FIG. 10. PLAN AND ELEVATION OF AN INDIAN PASSENGER BOAT SIMILAR TO THE ONE SHOWN ABOVE.

sets of compound surface-condensing engines.

The service of steamers on the Thames, at London, has never done justice to the splendid waterway which the river should afford. The reason for this is very simple. The facilities for landing are inadequate and are heavily taxed, and, at the same time, the approaches to the piers are, in many cases, narrow and unpleasant. Tolls have been abolished on the high roads, but, to gain access to the most beautiful highway in London, pier dues must be paid.

But for this, it is probable that the scheme of the Tramways Company, which was proposed in 1895, would have been carried out. In this scheme it was designed to construct a number of vessels adapted to convey passengers with comfort in all weathers and throughout the year. These vessels were, at the same time, to be of sufficient speed to be not unduly retarded by the rapid current found at

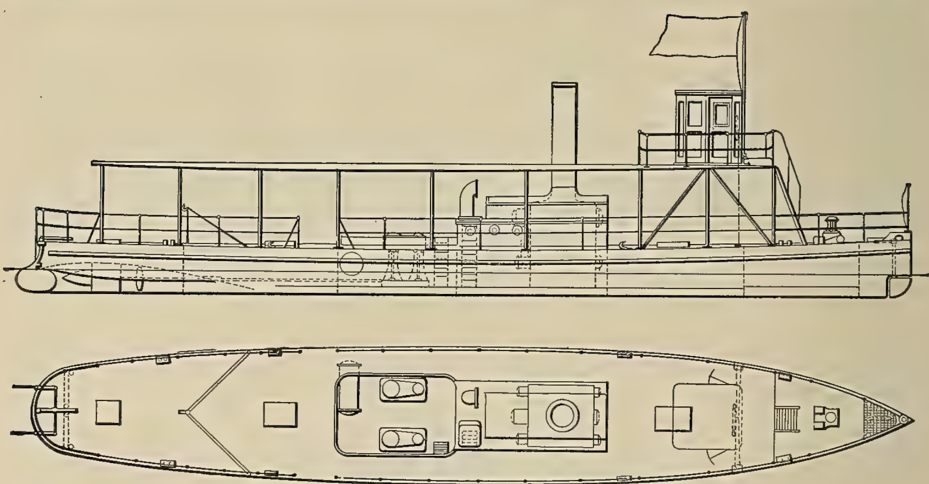


FIG. II. A SHALLOW-DRAUGHT TUG WITH RUDDER BOTH FORWARD AND AFT TO GIVE BETTER CONTROL WHEN GOING ASTERN.

FIG. 12. THE TURBINE-PROPELLER OF A PASSENGER BOAT FOR INDIA.

low tide when the water is also shallow.

With this object in view, a number of plans were made, the one finally proposed being a plan for turbine-propelled vessels designed by Messrs. John I. Thornycroft & Co., of London. The service of steamers on the Seine, at Paris lit by electricity and with every comfort for a short journey, illustrates what is necessary in pier accommodations, for in Paris you find that the boats going up the river do not call at the same landings as those going down. This saves much time, and is the only reasonable plan to pursue.

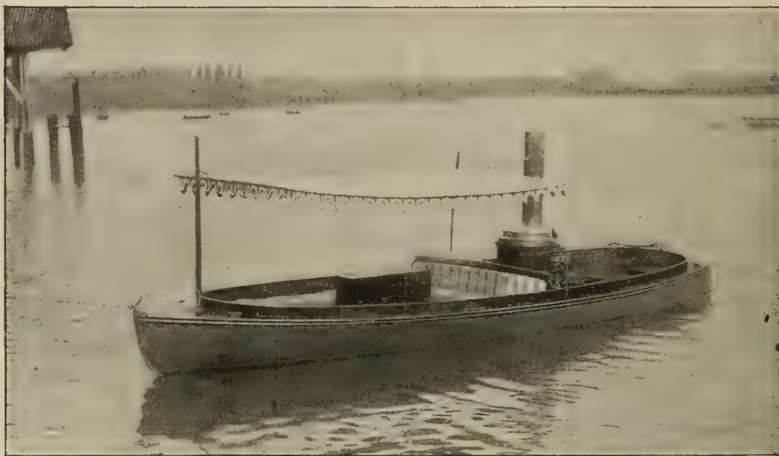
With regard to the Seine steamers themselves, they are very efficient boats, and the river being much deeper than the Thames, there is no difficulty from shallow water. Consequently the boats have single screws, giving a good speed for the power employed, but the vessels are too small to be very comfortable or fast.

In the transactions of the Institution of Naval Architects for 1861 there is a very interesting paper by Mr. Norman Scott Russell on American river steamers, showing how very well these vessels were adapted for the service for which they were designed, their large dimensions enabling them to give a high rate of speed with a moderate power. That the machinery was very heavy for the power attained was due to no fault of the constructors.

The radial wheels employed limited the revolutions of the engines to about twenty per minute. With this rate of turning, it is quite impossible to construct light machinery, and also in the boilers much weight was necessary due to the cylindrical type, then the only one available. In these vessels which carried accommodation, which can be compared to a floating hotel, the upper structure was a load evenly distributed, but the machinery and the boilers constituted two very heavy loads which were so concentrated as to require much skill in staying the light wooden hull, so as to prevent change of form without adding too much weight.

In narrow rivers it has been found necessary to place the wheels at the stern when paddle wheels are used, but this construction requires additions to be made to strengthen the hull. It is, therefore, probable that the fastest paddle boats can be built with the wheels near the centre of the vessel, but so placed that the system of waves accompanying the boats does not prevent the paddles having proper immersion. With

boats in which very high power has been provided this becomes important and one, at least, of the Clyde firms has made a special study of this subject by shallow-draught boat and could, perhaps, be displaced by a twin screw vessel with economy. The modern paddle, however, has an avdantage over those



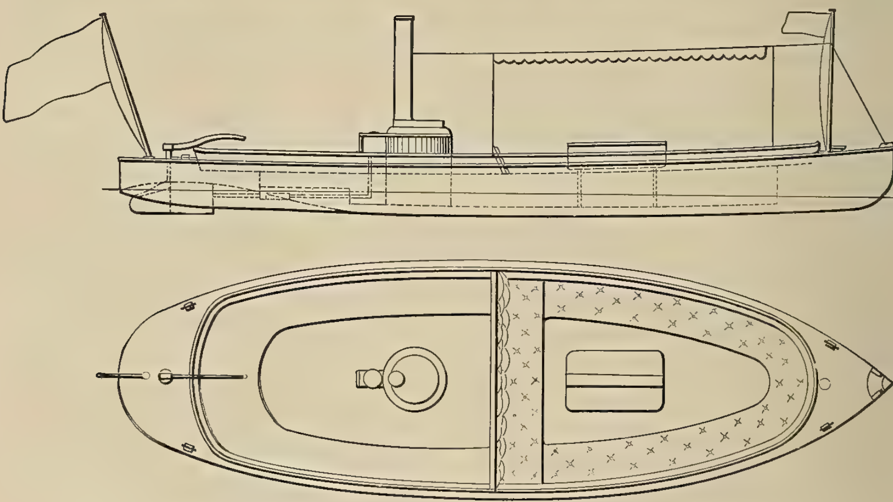


FIG. 13. THE PLEASURE LAUNCH "QUEEN OF THE VALE." LENGTH, 25 FEET. BREADTH, 8 FEET. DRAUGHT, 10 INCHES.

driving models in an experimental tank with their own paddles, at a speed corresponding to that at which the vessels are to work. Even this is an expensive experiment, but less so than altering the position of the paddle shaft of a large steamer after it has been completed.

The modern paddle boat for channel service is scarcely within the scope of the present article, as it is not even a used in the boats described by Mr. Scott Russell, due to the fact that feathering paddles are adapted to be used of a smaller diameter than radial wheels. The engines, therefore, can be run faster; but the most suitable propeller at present designed for high-speed vessels of limited draught, is the turbine-propeller, fitted to a suitable form of vessel as here illustrated.

THE DESIGN AND BUILDING OF A STEAMSHIP.

By Archibald Denny, M. Inst. N. A.

TO correctly design a steamship the naval architect must draw from a store of information gradually accumulated either by himself or by his predecessors. In a well organised office the technical data of vessels built is most carefully tabulated in an easily accessible form for such items as weights, cubic capacities, stability and speed; these data are generally put in the form of co-efficients of the principal dimensions, so that rough approximations may, in the first instance, be arrived at, before the final design is taken in hand. The process of design can perhaps best be described by taking a concrete case. We will assume that a shipbuilder has been asked by a prospective owner to design a cargo ship, about 320 feet in length, to carry a dead weight of at least 4500 tons, on a draft of about 23 feet 3 inches, at a speed of 10 knots at sea. From his previous experience the designer chooses, let us assume, dimensions 320 feet by 40 feet by 29 feet 6 inches, and he must now, by rough calculation, see if these dimensions approximately meet the conditions.

The first thing is to calculate the weight of the hull. For convenience the hull weight is usually divided into two parts,—first, the steel work proper; and, second, what is generally called "wood and outfit." This latter comprises all the remainder, such as decks, cabin fittings, anchors and chains, cement in the bottom, rigging, small

FIG. I. SHAPING A SHIP'S FRAME.

FIG. 2. A DOUBLE BOTTOM NEAR COMPLETION.

boats, deck machinery, etc., etc. Each designer has a somewhat different method, but a convenient one is as follows:—

Multiply the three dimensions together, namely—length, breadth, and depth, and divide by 100; the result is known as the " cubic number," and in this case, is $\frac{320 \times 40 \times 29.5}{100} = 3775.$

It is found, by experience, that the weight of invoiced steel, that is, the material as it enters the ship yard, including rivets and forgings, bears a roughly constant relation, for similar ships, to this cubic number. This coefficient of invoiced steel is tabulated for many vessels, and by choosing a vessel which most nearly approaches in dimensions and style the one under design, the weight of invoiced steel will be arrived at approximately. This co-

efficient varies, according to type of vessel, between large limits, say, 0.32 to 0.55. In such a steamer as this, it may be taken at 0.40; thus $3775 \times 0.4 = 1500$ tons. In a similar way the "wood and outfit" co-efficient is found to vary between 0.05 and 0.25. In such a steamer as this it would be about 0.1; then $3775 \times 0.1 = 377.5$, say, 380 tons.

In the process of being worked into the ship, a certain amount of invoiced steel becomes scrap; 12 per cent. is a suitable allowance to make for this, and the result of the calculation is then as follows:—

Invoiced steel	=	1500
Less 12 per cent	=	180
Net steel	=	1320
Wood and outfit	=	380
		1700

We have, then, 1700 tons as the weight of hull.

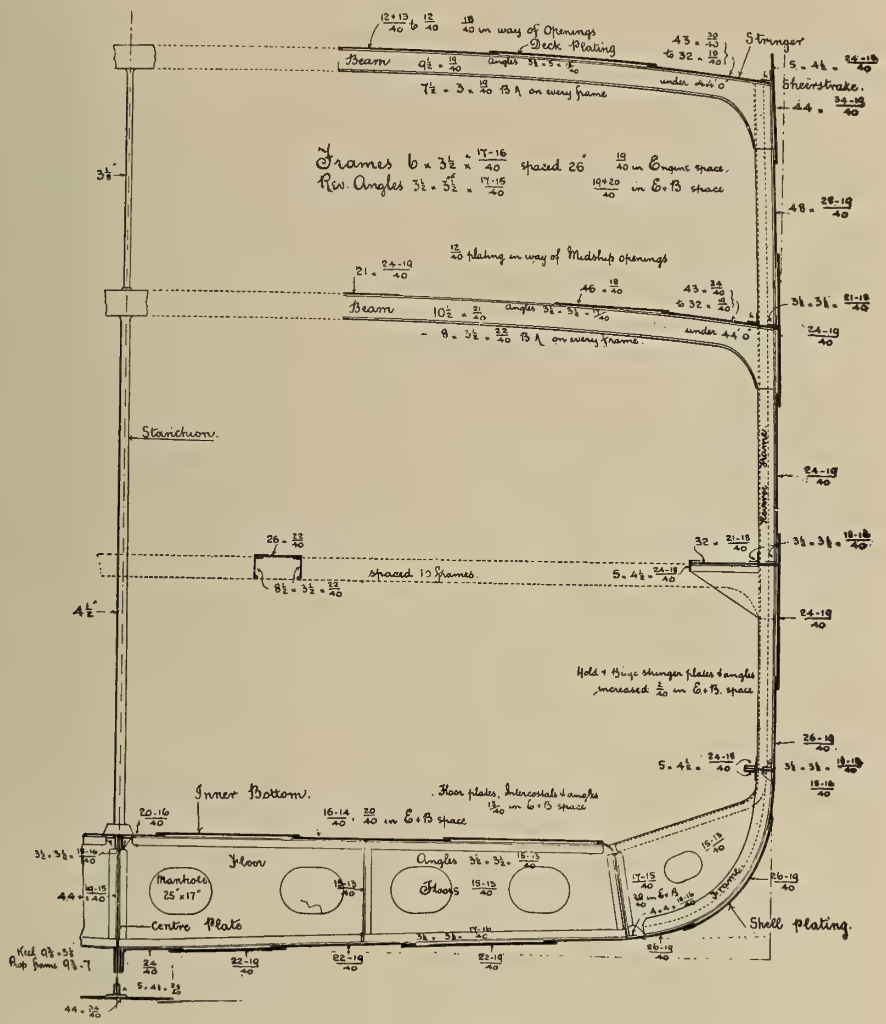


FIG. 3. A MIDSHIP SECTION, SHOWING THE MAIN SCANTLINGS OF A SHIP.

To fix upon the correct weight of the propelling machinery is, in the case of a specially fast passenger steamer, difficult, but the type of steamer under con-

FIG. 4. THE FRAME NEARLY FINISHED.

sideration is such a common one that the process is easy, and the weight of machinery is so small in comparison to the total displacement of the vessel, that a slight error in the first approximation is of small consequence. An experienced designer would know that for a vessel of this kind about 1500 horse-power would be necessary to ensure the desired sea speed, and it is possible to get 5 I. H.-P. per ton weight of machinery in such a type of engine; hence the weight of the engines would be 300 tons.

This, added to the weight of the hull, makes a total light weight for this vessel of 2000 tons, and, hence, the total displacement, at the load draft of 23 feet 3 inches, must be 6500 tons. Such a vessel at such a speed does not require fine lines, and the designer would be quite prepared to build a ship of which the "block co-efficient" would be 0.78. The block co-efficient is the ratio of the actual displacement to the displacement of a box, whose length and breadth are that of the ship and whose depth is the draft of water; hence in this case the block co-efficient is 0.773.

The next step is to actually design, not only all the general arrangements involving the position of machinery, the position of bulkheads, hatches, deck machinery, and cabin accommodation, but also to design the scantlings. While the deck plans and profile are being prepared, the midship section, which shows the main scantlings of the vessel, and of which Fig. 3 is an example, is got out.

Nowadays very little latitude is left to a designer, especially in vessels of this type, as the builder has generally to conform to the rules of some registry society and obtain their classification. Of these societies there are a considerable number, the most important are Lloyd's Registry for the British and Foreign Shipping, the French Bureau Veritas, and the British Corporation for the Survey and Registry of Shipping.

FIG. 5. THE UPPER DECK, SHOWING PLATING IN PROGRESS.

Classification has now become practically compulsory in the United Kingdom since the passing of the 1890 load line act, and these three bodies are licensed by the Board of Trade to assign freeboards along with that Board. Now a freeboard can only be assigned when a vessel is up to a certain standard of strength, and must be assigned by one of the above mentioned bodies, and it will thus be seen that a designer's originality is much restricted. It is fortunate, however, that we escaped the imposition of a monopoly in the assignment of freeboards which nearly became law in 1890, or even the small freedom which is now left a designer, would by this time have practically vanished.

The designer, therefore, in preparing his midship section has simply to turn up the rules of the registry society chosen, where he will find the scantlings for the ship of the dimensions chosen, given with more or less clearness. Having got the midship section, he proceeds to check his rough calculation by the more accurate process of scheduling all the steel material, either by detailed calculation, if time be available, or by some more or less elaborate scheme of co-efficients. The "wood and outfit" is similarly treated, and if the first calculation has been made with sufficient care, this result should agree substantially with it. To check the power calculation, the methods are varied and numerous. One designer employs one method, and an other some

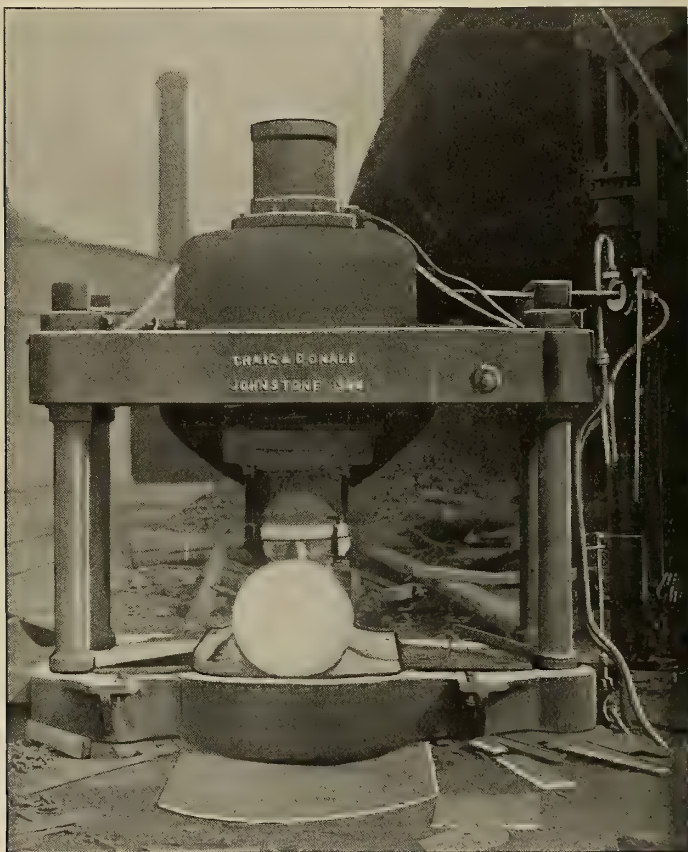


FIG. 6. A HYDRAULIC MANHOLE PUNCHING MACHINE.

FIG. 7. THE STERN TUBE, RUDDER AND ONE OF THE PROPELLERS.

other, the oldest method being, probably, by what is called the "Admiralty Constant." Why it is called a constant is difficult to say, as it is absolutely inconstant. The formula expressing this constant is as follows:—

$$C = \frac{D^{2/3} \times V^3}{I.\ H.\ P.},$$

where C is the constant; D, the displacement in tons; V, the speed in knots, and $I.H.P.$, the indicated horse-power.

The designer has probably among his data the result of progressive trials on a measured mile for many steamers, and for a speed such as the one with which we are dealing, this "Constant" method is perhaps as accurate a one as any other of arriving at the necessary power. From his data he chooses a steamer which most nearly approaches the one he is designing. If the vessel happens to be of precisely the same length, he takes the constant for 10 knots from the constant curve; then, inverting the equation, he has

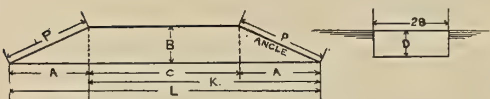
$$I.\ H.\ P. = \frac{D^{2/3} \times V^3}{C}.$$

In this case we shall assume a constant of 290 and the equation then solves as follows:—

$$\frac{350 \times 1000}{290} = 1200.$$

This would be sufficient for trial trip

MOULDED DIMENSIONS	320′ × 40′ × 29·5′
MOULDED DRAUGHT	23·14′
DISPLACEMENT	6540 TONS.
MIDSHIP AREA.	904 SQ. FT.



$$K. = \frac{6540 \times 35}{904} = 253{\cdot}3' \qquad A = L - K = 320' - 253{\cdot}3' = 66{\cdot}7'$$

$$B. = \frac{904}{23{\cdot}14 \times 2} = 19{\cdot}52' \qquad C = K - A = 253{\cdot}3' - 66{\cdot}7' = 186{\cdot}6'$$

$$\text{TANGENT OF ANGLE} = \frac{19{\cdot}52}{66{\cdot}7} = {\cdot}2926 \quad \text{ANGLE } 16^\circ\text{-}19'$$

$$P = A \times \text{SEC } 16^\circ\ 19' = 66{\cdot}7' \times 1{\cdot}0426 = 69{\cdot}5'$$

$$\text{BOTTOM SURFACE} = 506{\cdot}6 \times 19{\cdot}52 = 9890$$

$$\text{SIDE} = 325{\cdot}6 \times 46{\cdot}28 = 15070$$

$$24960$$

$$\text{PRISMATIC COEF} = \frac{6540 \times 35}{320' \times 904} = {\cdot}791$$

$$\otimes \text{ AREA} = \frac{904}{40' \times 23{\cdot}14'} = {\cdot}977$$

$$\text{BLOCK} = \frac{6540 \times 35}{320' \times 40' \times 23{\cdot}14'} = {\cdot}773$$

SPEED ESTIMATE S. S. 320′ × 40′ × 29·5′

	PROPOSED S	TYPE A.	TYPE B.
LENGTH MOULDED L	320′	317′	320′
BREADTH " B.	40′	40·17′	42′
DRAUGHT " D	23·14′	21·56	15·75
DISPLACEMENT Δ	6540	6050	4360
MIDSHIP AREA	904	840	632
PRISMATIC COEFF.	·791	·795	·755
MIDSHIP AREA "	·977	·970	·955
BLOCK	·773	·771	·721
$\frac{L}{B}$	8·00	7·89	7·61
$\frac{D}{B}$	·579	·537	·375
LENGTH OF ENTRANCE	66·7′	64·9′	78·5′
ANGLE	16° 19′	16° 42	14°-20′
SURFACE	24960	23740	19930
RATE AT 10 KNOTS.	4·75	4·80	4·40
I. H. P " " "	1200[x]		
WEATHER AT TRIAL.		FINE	FINE
$\frac{V^3 \times \Delta^{2/3}}{I\,H\,P}$	$\frac{1000 \times 350}{1200} = 290$		

[x] ADD 25% FOR SEA WORK SAY 1500 I. H. P.

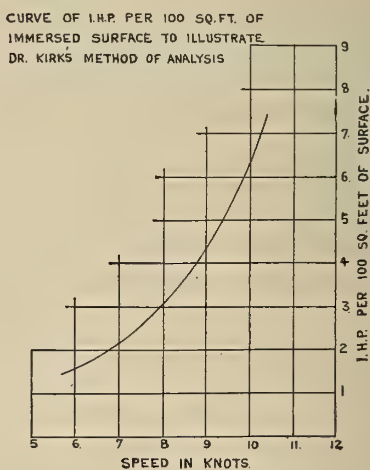


FIG. 8. RATE CURVE AND ACCOMPANYING CALCULATIONS.

purposes, but a certain percentage must be added for sea work, say, in this case, 25 per cent. = 300 I.H.-P., and 1200 + 300 = 1500.

This equation was originally evolved upon the assumption that the resistance varied as the square of the speed and as the wetted surface and it will be observed that $D^{2/3}$ for similar ships is roughly an expression for the wetted surface.

While it is true that the resistance varies as the square of the speed for low speeds, it is very far from true for high speeds. The resistance of a vessel passing through the water is made up of two principal elements; first, skin friction, and second, wave making.

At low speeds, skin friction entirely dominates wave making; at high speeds wave making becomes the principal element. It is here that model experimental data become of particular value, when the speed is high, and when examples of similar high speeds are not within the practice of a designer. Dr. Froude, by the invention of the experimental tank, has greatly assisted in the solution of such difficult problems.

The only other method of solving the "power for speed" problem, which will be touched upon, is that invented by the late Dr. Kirk, and known as "Kirk's analysis."

Instead of using $D^{2/3}$ to express the surface, by his method from the geometrical properties of the under-water part of the hull, he arrives at an empirical

FIG. 9. THE "SOUTHWARK" ON HER TRIAL TRIP. BUILT BY MESSRS. WM. DENNY & BROS., DUMBARTON.

surface, and instead of plotting the results of progressive trials in the form of "Admiralty Constant" curves he plots the results in the form of rate curves using spots obtained as follows:—For each speed at which a vessel is tried he divides the power by the number of hundreds of square feet in his empirical surface, and an example of this is shown in Fig. 8. Instead of using the lines of the ship, for the purpose of preliminary investigation, when the lines of the proposed vessel are non-existent, he imagines a wedge-shaped ship, as shown in the figure, having the same draft, length, and displacement, as the actual ship, and he thus further facilitated the guess which must be made in fixing the rate to be chosen, by obtaining an empirical length of entrance, called *A*.

In working Kirk's method, the proposed ship is reduced to a wedge-shaped block and the results are tabulated as shown. Several other similar ships which have been tried on a measured mile are tabulated in the same way, and by comparing their lengths, breadths, drafts, fineness, and the empirical lengths of entrance, *A*, the designer decides what the proper rate should be for the proposed ship. With sufficient data and a combination of "Admiralty Constant," and Dr. Kirk's method, for a vessel of ordinary speed, there should be no difficulty in arriving at a correct conclusion. The consideration of the engines now passes out of our province, the remainder of the work upon their design is carried out by the marine engineer.

The plans having been completed, and approved of by the owner, the next part of the shipbuilder's work is to estimate the cost, but although this and the securing of the order are perhaps two of a shipbuilder's most important functions, the method of estimating the cost is so similar to that in most other mechanical trades, and the difficulty in securing the order is also such a common difficulty that we need not discuss them, but assume at once that our shipbuilder has been successful in making the contract.

The design and the carrying out of the work are simultaneous operations; in fact, the design is only completed when the vessel is finished. Numerous small details crop up at the very last moment, which have to be tackled in the drawing office, but the first operation in the drawing office is to order the keel centre plate, frames, reverse frames, floors, beams, bulkheads, stem and stern post, in the order named.

The necessary constructive plans are prepared at the same time, and are passed out to the iron foreman, so that

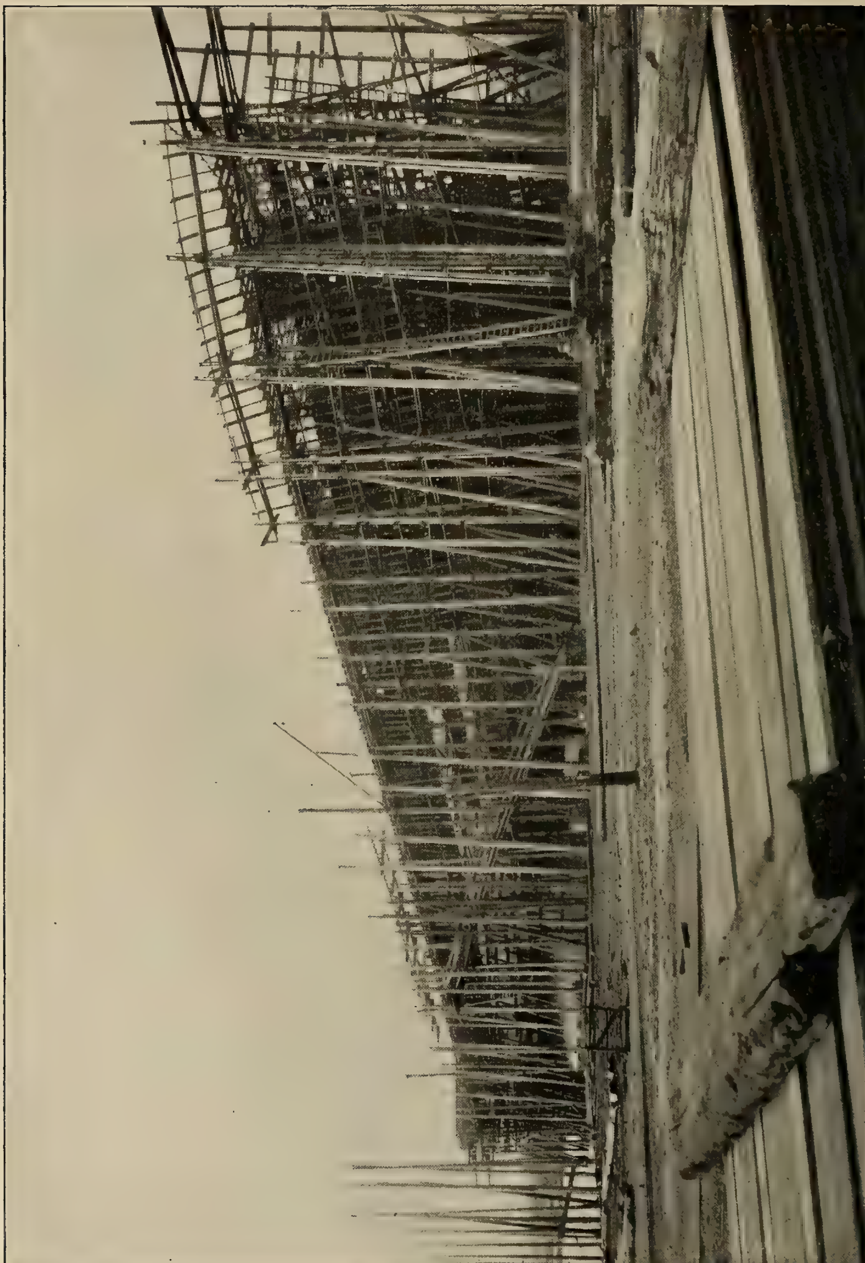


FIG. 10. READY FOR THE OUTSIDE PLATING.

as soon as the material arrives in the yard he may proceed with his work. Next, the shell, inner bottom, and deck plating, casings, and other materials are ordered, and the necessary working plans for this, the deck and cabin work, and all the other plans are then carried on.

The ship is generally laid down full size, on the moulding loft floor, and from the lines thus laid down each frame* is lifted on wooden battens, and transferred to what is known as the "boards." This is a large wooden floor in the vicinity of the cast iron bending blocks and furnaces. Each frame is separately drawn or scrived in with a graving tool upon this wooden floor, and from these scrives the framer lifts the shape and transfers it to the blocks in front of the furnace.

Fig. 1 is from a photograph of these blocks in a furnace shed, where a frame, after having been bent, is turned up to show its shape. This figure also shows, immediately behind the frame, the plate rolls which are used for bending plates, and to the left the punches and shears for punching the rivet holes and shearing the edges of the plates. The majority of the rivet holes in a frame angle in both flanges are punched before the frame is bent. Thirty-six holes per minute is considered to be a good speed for punching these frames, which, when delivered into the yard, are known colloquially as "green stuff." The reverse frames are punched and bent in a similar fashion and the floor plates, which are also scrived upon the boards, are sheared to shape and punched after having been templated from the frames and reverse frames.

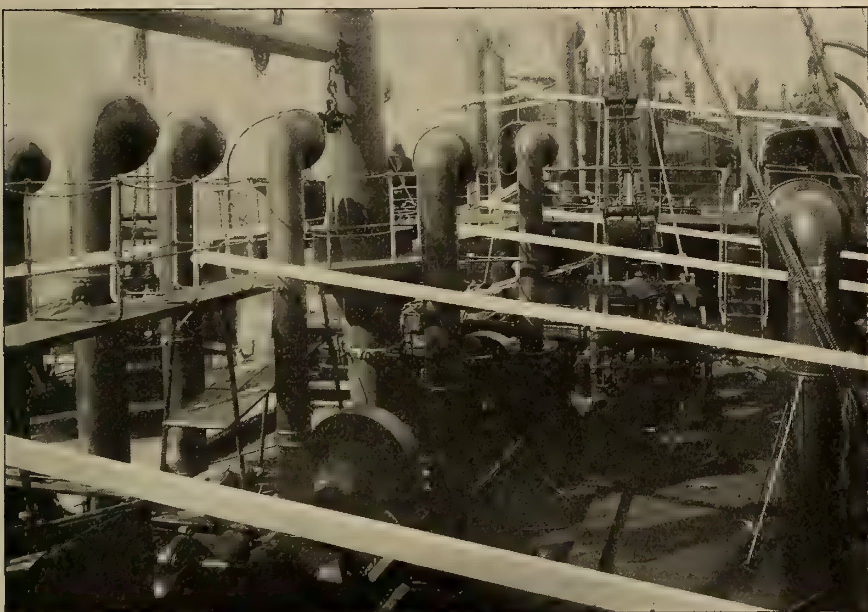


FIG. 11. THE UPPER DECK OF A COMPLETED STEAMSHIP.

Fig. 6 shows a large hydraulic manhole punching machine, capable of punching manholes in the floors up to 25x17 inches at one operation. The illustration also shows one of these punchings in the fore ground.

While the frames and the reverse frames are being bent and the floors prepared, the building blocks are got into place. These are simply square

* The frames are generally spaced about 2′ apart.

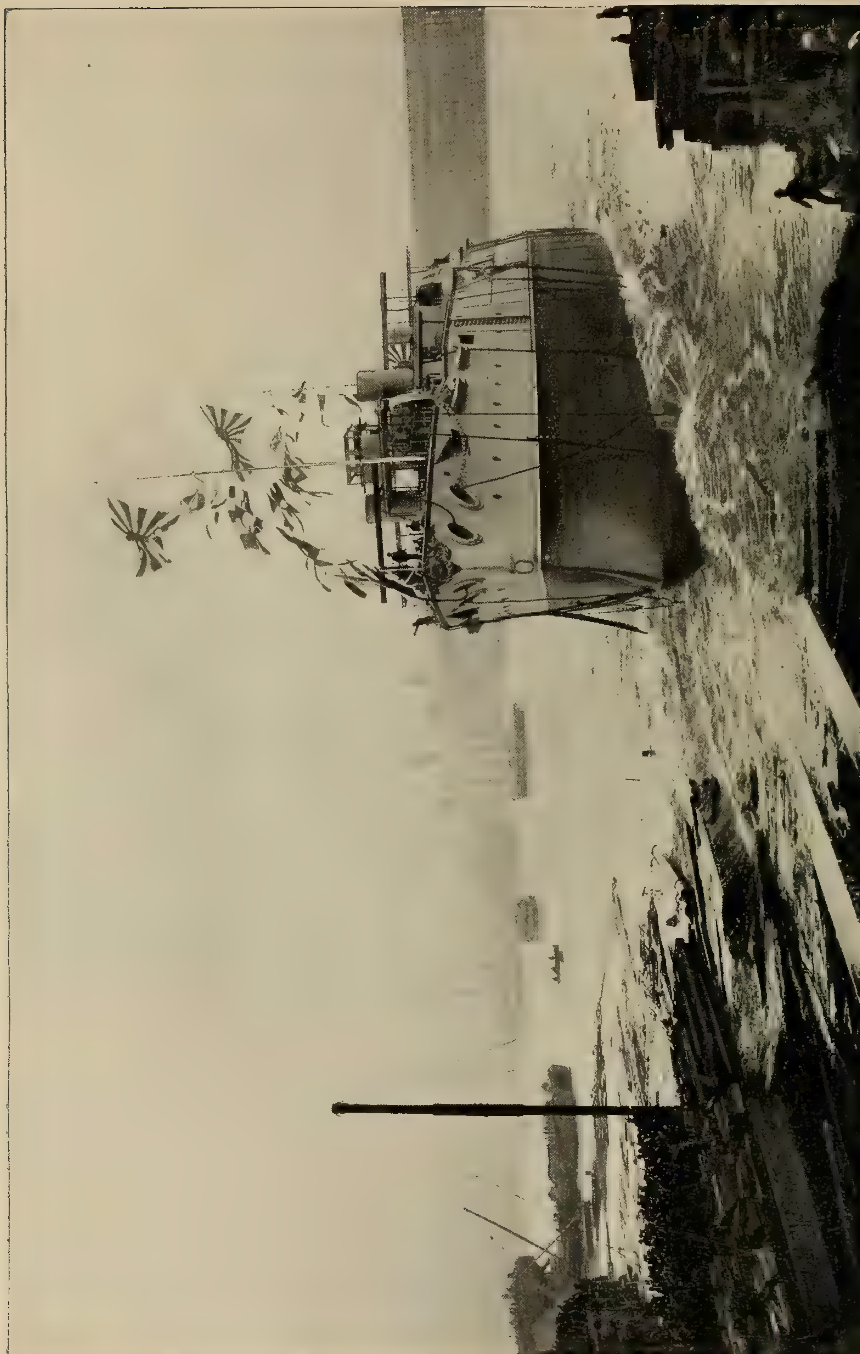


FIG. 12. THE LAUNCH OF THE JAPANESE BATTLESHIP "YOSHINO" AT THE YARD OF SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE.

billets of timber, from one to two feet square in section, piled one on top of the other to the requisite height.

Most modern steamships are now fitted with double bottoms. These serve the purpose of making provision for water ballast to ballast the ship when cargo is not available, but perhaps the principal advantage is the additional

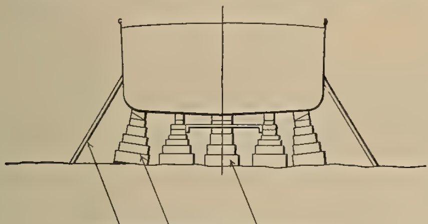


FIG. 13. METHOD OF SUPPORTING A VESSEL DURING CONSTRUCTION.

safety possessed by a ship so fitted. Frequent cases have occurred where a ship, having run ashore, has had her outer bottom pierced and largely destroyed, and yet the inner bottom remaining intact, the ship has proceeded on her voyage and arrived safely in port without those on board being fully alive to the large extent of the damage.

Where a ship is fitted with a double bottom, the first operation is to place on the blocks the keel and the centre plate already punched and fitted with angles to receive the floors on each side. Fig. 2 shows a double bottom almost completely erected. This photograph represents the construction of the T. S. S. *Southwark*, and shows the details of construction very well.

Fig. 4 is from a photograph of the same ship, taken at a later date, and shows her almost completely framed, and with part of the double bottom plating in place, the beams partly erected, and a bulkhead in the back ground. The *Southwark* was built upon the deep-frame system. The part marked "173" in white, shows such a deep frame. These were fitted about every sixth frame, the frames being 30 inches apart. An intermediate frame will be seen immediately in front of the plate frame. These intermediate frames in this case serve merely to stiffen the plating. The greatest part of the strain is ultimately transferred to the plate frames.

When completely framed, or even in some cases when partially so, the outside plating is gone on with, and Fig. 10 shows the same steamer in that position. The plating will be seen partly fixed in the middle of the ship. This photograph also illustrates well the staging arrangements which surround the ship, so that the workmen may get at the sides of the vessel. The riveters generally follow closely upon the heels of the plater, and permanently fasten the plates, which the latter has left secured by service bolts.

Fig. 5 shows the upper deck of the *Southwark* with the deck plating in progress. This photograph also shows the precautions taken, by means of heavy baulks of timber, to keep the beams fair and in line while the plating is proceeding. The beams are also supported by temporary wooden shores from below for the same purpose. Fig. 7 is from a photograph showing the stern tube, rudder and propeller of the *Southwark*.

When twin screws were first introduced, the outer end of the propeller shaft was supported by what was known as an *A* frame, from its resemblance to the first letter of the alphabet. This has for some years been largely dis-

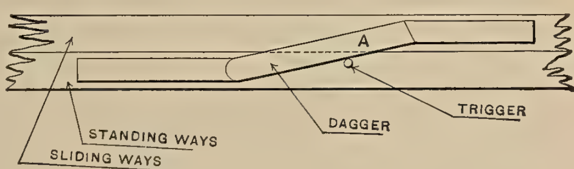


FIG. 14. RELEASING GEAR FOR VESSEL TO BE LAUNCHED.

carded in favour of building the stern tubes solidly into the general structure of the ship, and this plate well illustrates this method. Rudders also, until within a few years, were made of two plates, fastened to each side of horizon-

tal arms and thus forming a rudder of from 3 to 7 inches in thickness, the spaces between the plates being filled in either with wood or cement; but the modern practice is to construct the rudder of a single thick plate, securely riveted to arms alternately on opposite sides, as shown in the illustration.

When completely plated and riveted, and the wooden decks laid, the vessel is ready for launching, in order that she may be taken to a crane and have her machinery fitted on board. To describe in detail the launching operation would be to elaborate this article too much, but roughly the process is as follows:—

A line of blocks is placed on each side of the ship, as shown in Fig. 13, at about one-third of the half breadth of the ship out from the keel. On the top of these are placed what are known as the standing ways. These ways are inclined towards the water at a gradient of three-quarters of an inch per foot. In most yards the ways are slightly "hog backed," that is to say, the gradient is less at the fore end and increases towards the water. This is generally supposed to be done for the purpose of increasing the speed of the ship as she enters the water when the resistance to motion is also increasing, but there is another reason.

With ordinary ground, and even when the ground is absolutely solid, when the weight of the vessel comes upon the ways they are apt to sink locally and they might do so to such an extent, if laid at an equal gradient throughout, as to cause difficulty in launching, and some striking instances of this have occurred. On the top of these standing ways, which have been carefully covered with melted tallow, and grease or soft soap, are placed the sliding ways, and the space between the top of the sliding ways and the ship's bottom is carefully packed with wood blocks and wedges. The ship is thus in a species of cradle.

When the proper time arrives for the launch, the ship, which has up till now been supported in the centre by her keel blocks and at the sides by bilge blocks and shores, is, by the removal of these, allowed to come down upon the sliding ways. She is, however, prevented from launching herself by a locking arrangement shown in Fig. 14. This arrangement varies in different yards, but that shown is, perhaps, one of the oldest and most reliable. The diagonal timber, marked *A*, is called "the dagger," and is placed with its one end in an iron shoe fixed to the standing way and against a diagonal shoe on the sliding way. This arrangement is fitted on each side of the vessel. Generally the pressure against the dagger is sufficient to prevent it from falling, but as a safeguard a pin, called the "trigger," is fixed underneath to prevent it falling until the proper moment arrives.

When all the keel blocks, bilge blocks, and shores have been removed, the "trigger" is also removed, and at a given signal by means of a heavy hammer, or falling weights, these daggers are knocked out and the ship is thus free to glide into the water. She is then taken to a large crane or sheer legs, and her machinery is fitted in place, her deck work and cabin accommodations are completed, and she is ready for trial.

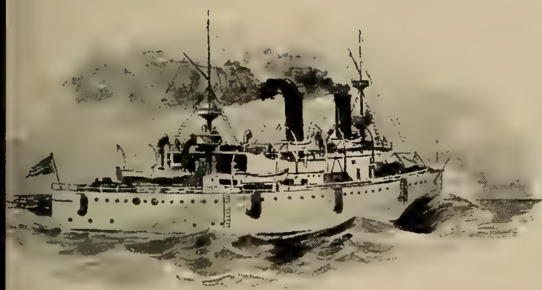
Fig. 11 is from a photograph of the upper deck of a completed steamer which shows, to some extent, the large amount of detail there is in a ship. Fig. 9 shows the *Southwark* when running at full speed on her trial.

The foregoing will give the reader some idea of how a ship is designed and built, but it gives no idea, nor does it pretend to do so, of the amount of detailed calculation and design involved in the construction of such a ship.

A few figures may be of interest. The steel work of the *Southwark* weighed 4300 tons; the number of separate plates and angles which had each to be ordered separately and of definite length, breadth and thickness was 17,000, and the number of rivets used to connect the various parts amounted to about 975,000. The total number of plans and tracings made for the *Southwark's* hull alone was 790.

WATER TUBE BOILERS FOR WAR VESSELS.

By Walter M. McFarland, U. S. N.



ALTHOUGH the name, water-tube boilers, is almost self explanatory, it may be well to define such a boiler as an apparatus for generating steam in which the whole, or almost all, of the heating surface consists of tubes of relatively small diameter which contain the water, or water and steam, the hot gases passing around the tubes. Thus the water is inside and the gases outside the tubes, while in the cylindrical or shell boiler the conditions are just reversed. In addition, the latter has a relatively thick shell to contain the water and steam while the water-tube boiler requires only a light casing to contain the gases and conduct them to the chimney or funnel.

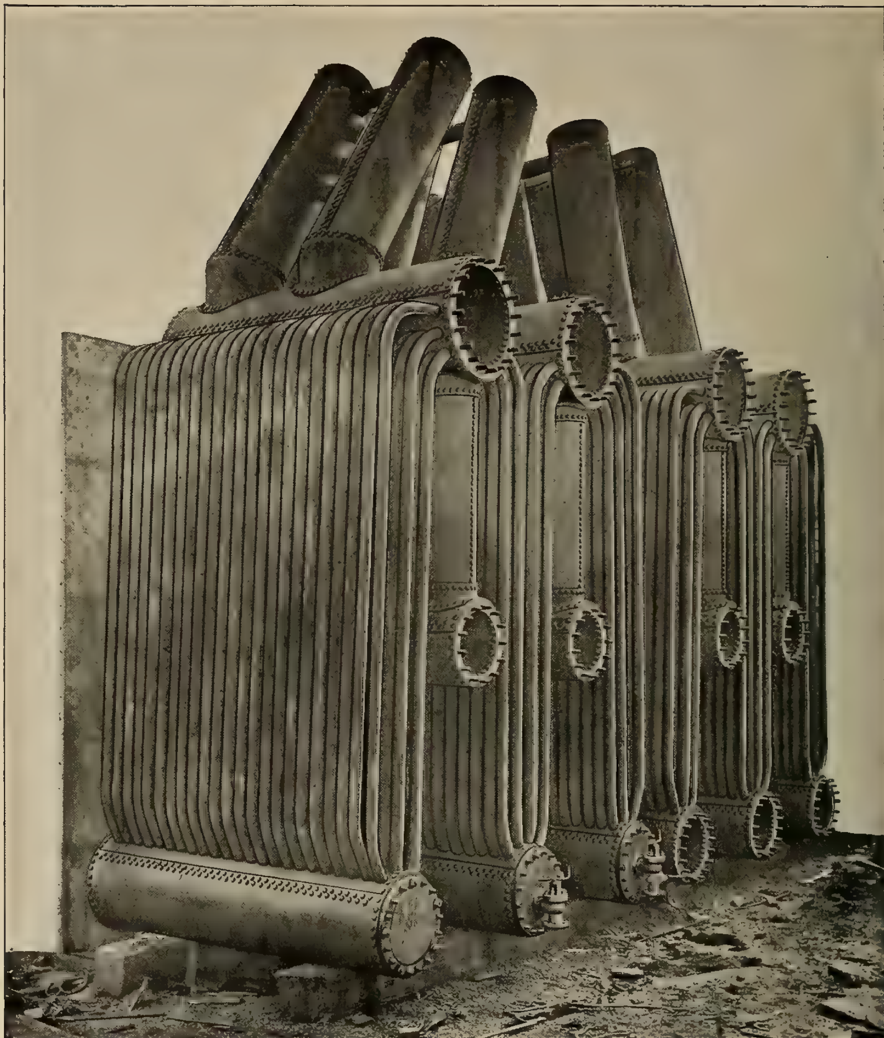
We shall be better able to appreciate the reasons which warrant the adoption of water-tube boilers on war vessels if we first take a brief survey of the history of the common type, known as the cylindrical, or Scotch, boiler. This is simply an adaptation of the still older "box" boiler to meet the requirement of higher pressures. In the box boiler, the shell was very thin and the strength was really dependent on the bracing. After a moderate steam pressure had been reached, the bracing would have had to be so close that the interior would have been inaccessible for cleaning.

The use of a cylindrical shell (the strongest form, except the sphere, in which the metal can be disposed) obviated the necessity of any bracing of the envelope, except the heads, so that the only long stays were reduced to a few in the steam space. As pressures slowly increased, it was at first merely a question of increasing the thickness of the shell, and, when the limit for wrought iron had about been reached, mild steel came in with its perfect homogeneity and reliability. Then, again, it was a question of thickness of shell, to which the steel makers were ready to respond, associated with improved design and workmanship in the riveted joints. Improved forms of furnaces were also brought out. In fact, the size of boilers grew until some have been produced 18 feet in diameter, 17 feet long, with shells nearly 1⅝ inches thick, containing 8 furnaces, and about 5500 square feet of heating surface.

In the early days a factor of safety as high as eight was often used in designing the shell, but with improved materials and the present methods of careful inspection and accurate determination of the strength, the factor of safety is as low as four and a half.

It would seem, however, as if we had now about reached the limit of pressure for the cylindrical boiler. The difficulty of making thicker plates of sufficiently large dimensions, and of properly working them, if they were obtainable, seems insuperable at present.

The rise in steam pressure, and improvement in material had enabled engine weights to be materially reduced by lighter scantlings and increased rotational speeds, so that, as the demand



WATER-TUBE BOILERS BUILT IN 1874 FOR THE STEAMSHIP "PROPONTIS," BY THE ORIGINAL FIRM OF JOHN ELDER & CO., GLASGOW.

for higher speeds of ships and consequent increased power of the machinery became urgent, it was necessary to reduce boiler weights per unit of power. This was accomplished by the use of forced draft, which did, indeed, greatly increase the power of the boilers, although at the expense of evaporative economy. The table below shows this very clearly, although the data are for a trial of a water-tube boiler. Exactly the same is true, in kind, of any boiler.

Table I.—Showing Variation of Economic Evaporation with Rate of Combustion, Boiler of U. S. S. "Cushing."

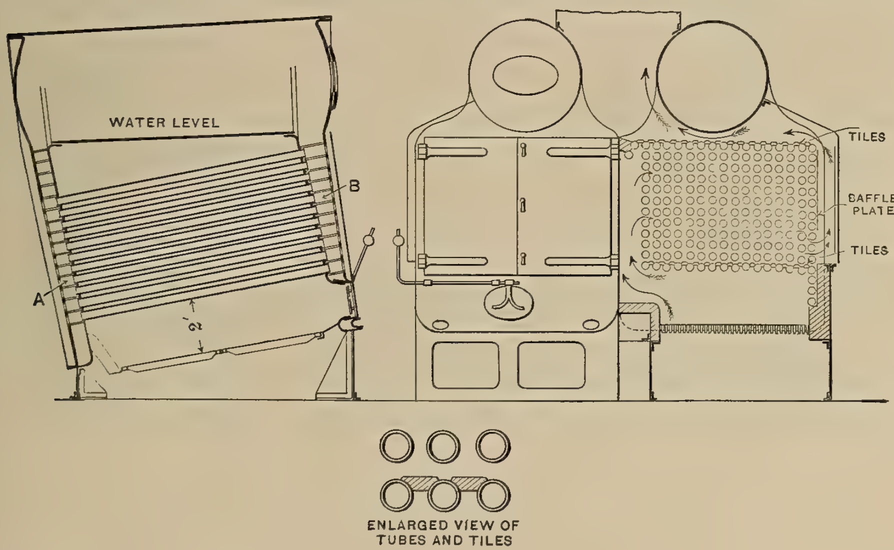
Air pressure in inches of water	0 00	0 50	3.00	4.00
Coal per hour per sq. ft. of grate	7.58	24.12	40.2[illegible]	66.[illegible]2
Water evaporated per pound of coal from and at 212° Fahr	11.90	9.72	8.84	6.51
Water per sq. ft. of grate per hour	90.20	234.40	355.60	431.80

This shows that, with a combustion of 7.6 pounds of coal per square foot of grate, the evaporation per pound of

coal was nearly 12 pounds, while when the combustion was increased to 66 pounds, the evaporation fell off to 6.5 pounds. In other words, an increase of boiler power of 380 per cent. is accompanied by a reduction of economy of about 45 per cent.

For war ships, where ordinary cruising is done at much below the natural draft power of the boilers, and where forced draft is used only occasionally, this reduction of economy might have been permitted, but unfortunately, forced draft has brought other evils. Probably every engineer, whether professional or amateur, has read of the trouble with leaky tubes in fire-tube boilers, used with forced draft, the most serious trouble having occurred in a lot of boilers built for the British Navy between three and seven years ago. A great many trial trips had to be abandoned on account of the leaky tubes, and, in some cases, the ships were not tried under forced draft at all. There great size of the boilers and the large amount of contained water compelled great care to be taken in raising and lowering steam to avoid leaks, caused by unequal expansion, this care involving a considerable time in raising steam. In fact, with the largest double-ended boilers from six to ten hours are allowed to get steam to full pressure after lighting fires. It can be seen at once that this would require the keeping of banked fires in all boilers in time of war, when steam might be wanted at short notice at any hour. Indeed, with these large boilers, almost the whole regimen has been changed from the easy, careless way in which older and smaller boilers were treated.

Owing to the great amount of contained water (which has its advantages from some points of view, as we shall see later) the explosion of one of these large boilers would be a frightful catastrophe, and would probably entirely wreck the ship. So far as the writer is



THE LAGRAFEL–D'ALLEST BOILER.

was even fear at one time that many of the boilers would have to be removed. This was averted by the invention of a ferrule for protecting the ends, which has proved quite efficient.

Another point to be noted is that the aware, however, there is no record of an explosion of one of the large modern boilers, which speaks well for all concerned in their design, manufacture and use.

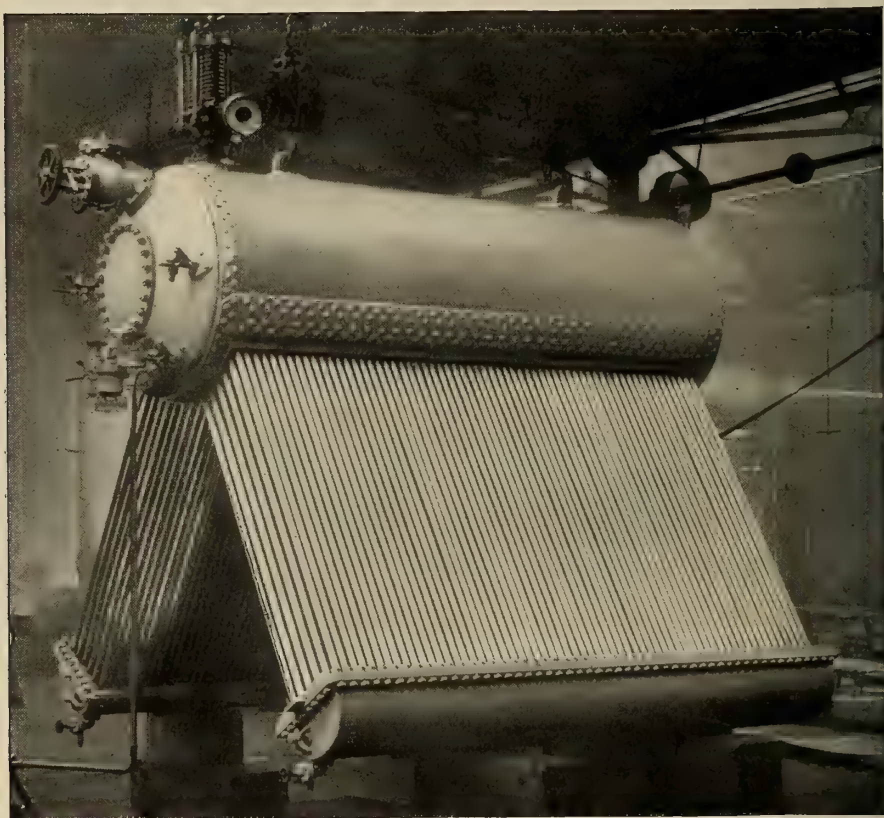
There have, however, been a number

of instances of ruptured steam pipes, both in war and merchant steamers, the latest being the accident last year on the American line steamer *St. Paul*, when half a dozen were killed. The greatest loss of life occurred on the German war vessel *Brandenburg*, when 45 were killed. The pipe broke in one of the engine rooms, giving free vent to the steam from twelve boilers, and as the two engine rooms were in communication, both were filled with steam. In the United States Navy, the main steam pipe of the *Concord* burst, filling one of the boiler compartments with steam, which *continued for about two hours*, preventing entrance. This is just the point,—that the large amount of contained water at a high temperature will continue to give off steam for a long time, so that it will be impossible to go into the compartment where the accident has occurred to succor those who may be injured, but not past help, if the latter could only arrive promptly.

From this brief survey, we conclude that the points of objection to the cylindrical or fire-tube boiler are:—

1. Inadequacy for pressures above 180 to 200 pounds.

2. The great weight of the structure itself and of the contained water.



A YARROW BOILER WITH ITS CASING REMOVED. MADE BY MESSRS. YARROW & CO., LTD., LONDON.

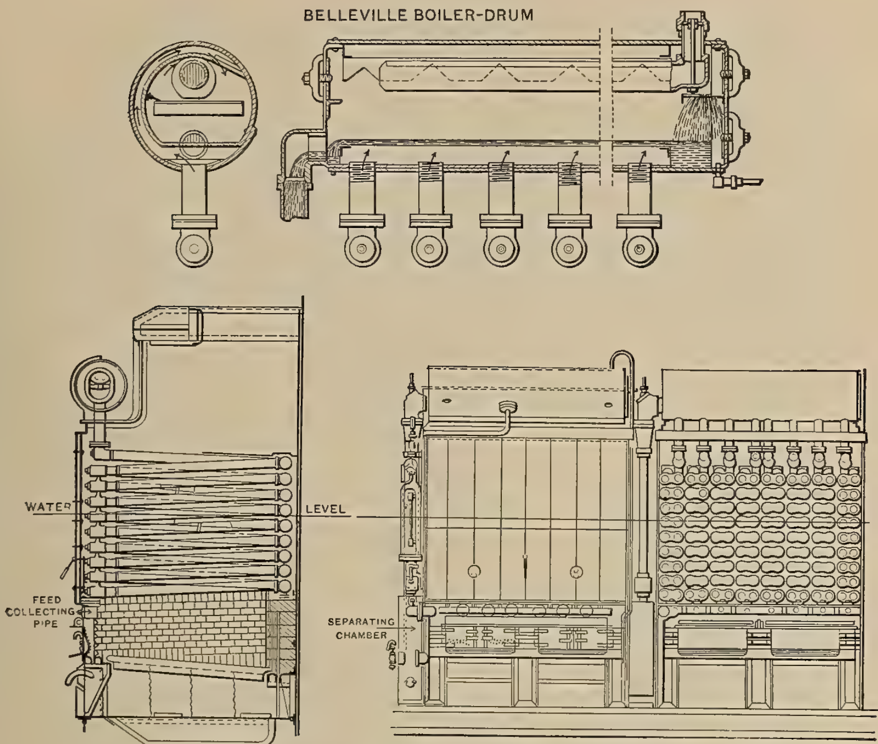
3. The liability to injury from forced draft.

4. The great care required to prevent injury from sudden changes of temperature.

5. Slowness in raising steam.

6. Increased danger in case of explosion of either boiler or steam pipe, due to large amount of contained water.

Let us now examine the case of water



A BELLEVILLE BOILER. MADE BY MESSRS. MAUDSLAY, SONS & FIELD, LTD., LONDON.

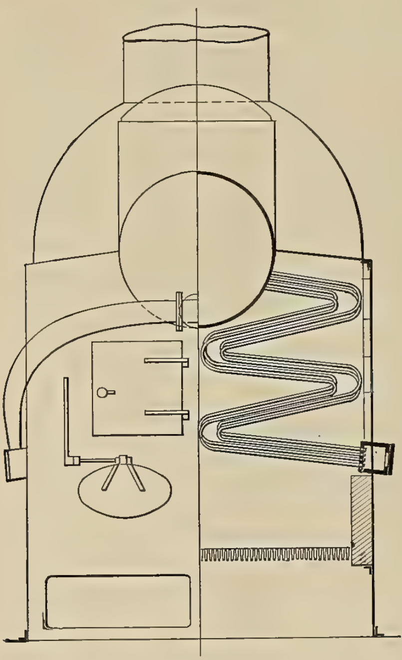
tube boilers and find how far they avoid these defects. As a type, water tube boilers may be said to consist of a mass of tubes, forming the heating surface, and uniting one or more steam drums at the top with one or more water drums, or their equivalents, at the bottom, the water being inside the tubes. They may be divided into two main classes, those having tubes of small diameter and those with tubes of large diameter. To the former belong those boilers which have already made a name for themselves on torpedo boats and yachts and a few large ships,—the Thornycroft, the Yarrow, the Normand, the Du Temple, the Ward, the Cowles, the Mosher, the Towne, and others—while the latter have been used mainly on larger ships and comprise the Belleville, the D'Allest, the Niclausse, the Babcock & Wilcox, and some others.

In the former, the tubes are not over 2 inches in external diameter, while in the latter they are rarely less than 3 inches. In the former, the tubes, though occasionally straight, are generally curved or bent, but in the latter they are always straight. The difference amounts to more than might be supposed at first and causes some statements that would otherwise be general, to apply only to the boilers with small tubes.

1. *Adequacy for High Pressures.*—The tubes themselves are of so small a diameter that they can readily be made safe for any pressure. The drums are the largest parts and they are still of such moderate dimensions that they, also, can be made of ample strength. Even in the case of those boilers which have water legs or sides consisting of flat, stayed plates, they can be made strong enough for any pressures likely to be used for many years to come. It may be said, therefore, that water-tube boilers are adapted to any pressure that may be desired.

2. *Reduction of Weight of Structure*

of Boiler and Contained Water.—In this respect the water-tube boiler has a marked advantage over the older type. Scarcely any bracing being required, the elimination of the thick shell, and the fact that the greater part of the boiler consists of the tubes, all combine to cause a material reduction of the weight of structure, while the amount of water contained is so small that it is only a fraction of that in the shell boiler of equivalent power. An examination of the data in Table II. of some boilers of both types will make these points clear.



THE DU TEMPLE BOILER.

The difference in weight per I. H. P. at full power is not very great for the two types, but this is largely because the cylindrical boiler is forced much harder. For this reason the comparison in the last three lines has been made on a natural-draft basis, in which case the water tube boilers are very much lighter per unit of power. It is to be noted also that the water tube boilers in this table have large tubes and are not so light as others of which data are given in Table III. on page 414.

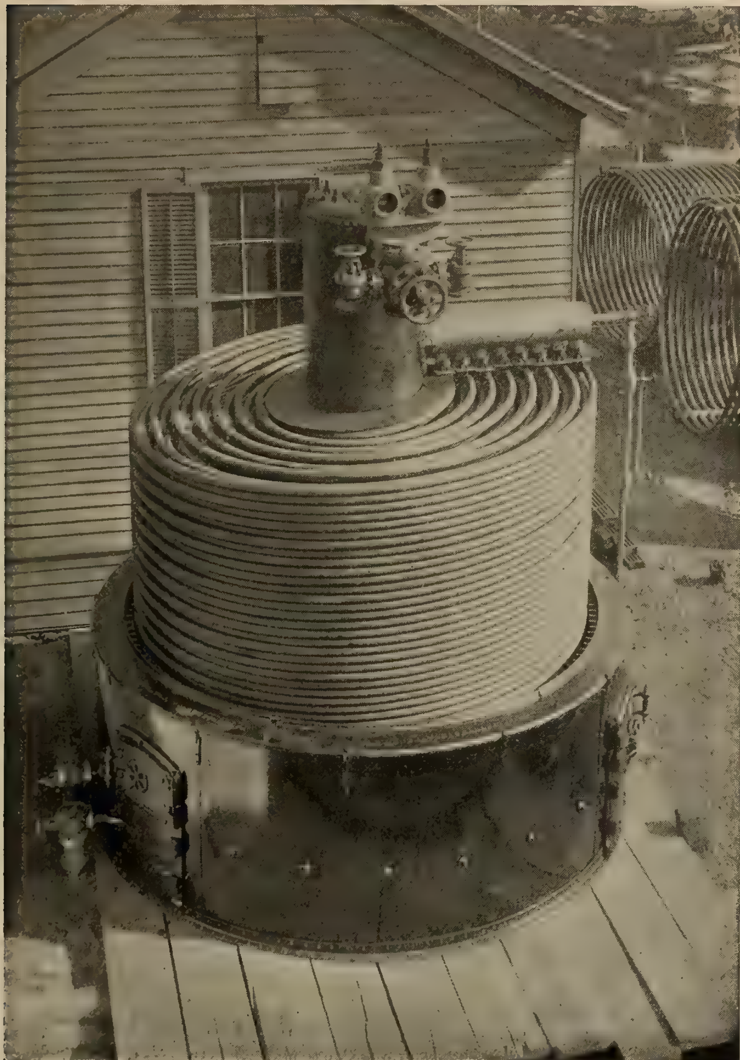
Since Table II. was prepared, some data of the trials of the boilers of the *Friant* have been published in *Engineering*. From these it appears that twelve of the twenty boilers were worked under forced draft for four hours, enabling the engines to develop 6842 I. H. P. At the same rate for all

Table II.—Comparison of Cylindrical Boilers of U. S. S. "Newark" and Water Tube Boilers of the "Chasseloup-Laubat" and "Friant" of the French Navy, in Each Case for about 9000 I. H. P.

Name of ship	*Newark.*	*Chasseloup-Laubat.*	*Friant.*
Type of boilers	Double-ended cylindrical.	D'Allest.	Niclausse.
Number of boilers	4	20	20
Number of furnaces, each boiler	6	1	1
Grate surface, one boiler, sq. ft.	135	36.6	39.1
Grate surface, total sq. ft.	540	732	783
Heating surface, one boiler, sq. ft.	4,185	972	1,167
Heating surface, total sq. ft.	16,736	19,451	23,338
Weight of one boiler, without water	47.80 tons.	11.46 tons.	10.92 tons.
Weight of water in one boiler	22.32 "	2.65 "	2.31 "
Total weight of all boilers and water	320.5 "	282.2 "	264.70 "
Total weight in fire rooms, including pumps, blowers, etc.	396.4 "	332.0 "	329.00 "
Weight (total in fire rooms) per sq. ft. of grate	1,644 lbs.	1,016 lbs.	941 lbs.
Weight per sq. ft. of heating surface	53.05 "	38.23 "	31.58 "
Weight per I. H. P. (9000)	98.65 "	82.62 "	81.88 "
Air pressure in inches of water	2.25	1.25	1.25
Coal consumption per sq. ft. of grate per hour	39 lbs.	31 lbs.	31 lbs.
Pounds of steam per hour with a combustion of 15 lbs of coal per sq. ft. of grate surface, from and at 212 deg. F.	81,000	109,800	117,400
I. H. P. at 18 lbs. of steam per I. H. P. from and at 212 deg. F.	4,500	6,100	6,520
Weight (total in fire rooms) per I. H. P. in last line	197 3 lbs.	121.9 lbs.	113.0 lbs.

the boilers, this would give the weight in fire rooms per I. H. P. at 64.63 pounds. The combustion was at the rate of 36 pounds per sq. ft. of grate. The figures in the table were prepared from the published data of the design of the machinery.

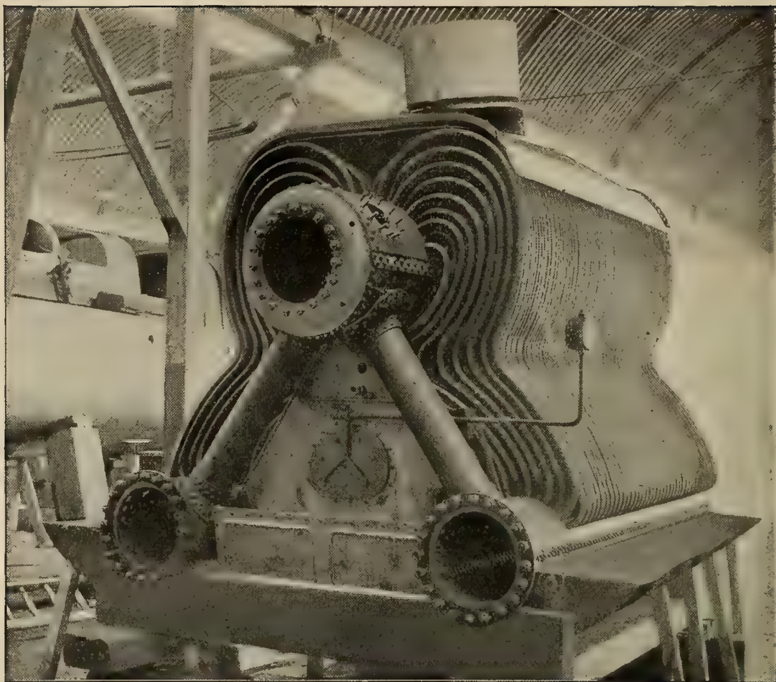
It is to be noted that the weights in this table are of the boiler and water only and do not include, as in the former



COIL BOILER. MADE BY CHARLES WARD, CHARLESTON, W. VA., U. S, A.

table, pumps, piping, blowers, etc. In the case of the U. S. S. *Newark*, the I. H. P. per ton of boiler and water works out only 32.5, which is less than half of any one of the three water-tube boilers, or in other words, the shell boiler is more than twice as heavy per unit of power as they are. Other examples might be given, but the result would be the same.

In this connection it may be said that the type of boiler which preceded the water-tube in torpedo boats,—the locomotive,—was the lightest of all the shell boilers, and, when forced hard, gave results as to weight per horsepower about equal to the water-tube, but as all the leading builders of torpedo boats, except one, have abandoned the locomotive for tubulous boilers of their own design, it shows that they are satisfied of the superiority of the latter. As late as 1893, Schichau, the famous German builder, still advocated



A STANDARD THORNYCROFT BOILER. MADE BY MESSRS. JOHN I. THORNYCROFT & CO., LONDON.

the locomotive type, but he, too, has since adopted water-tube boilers in his latest boats.

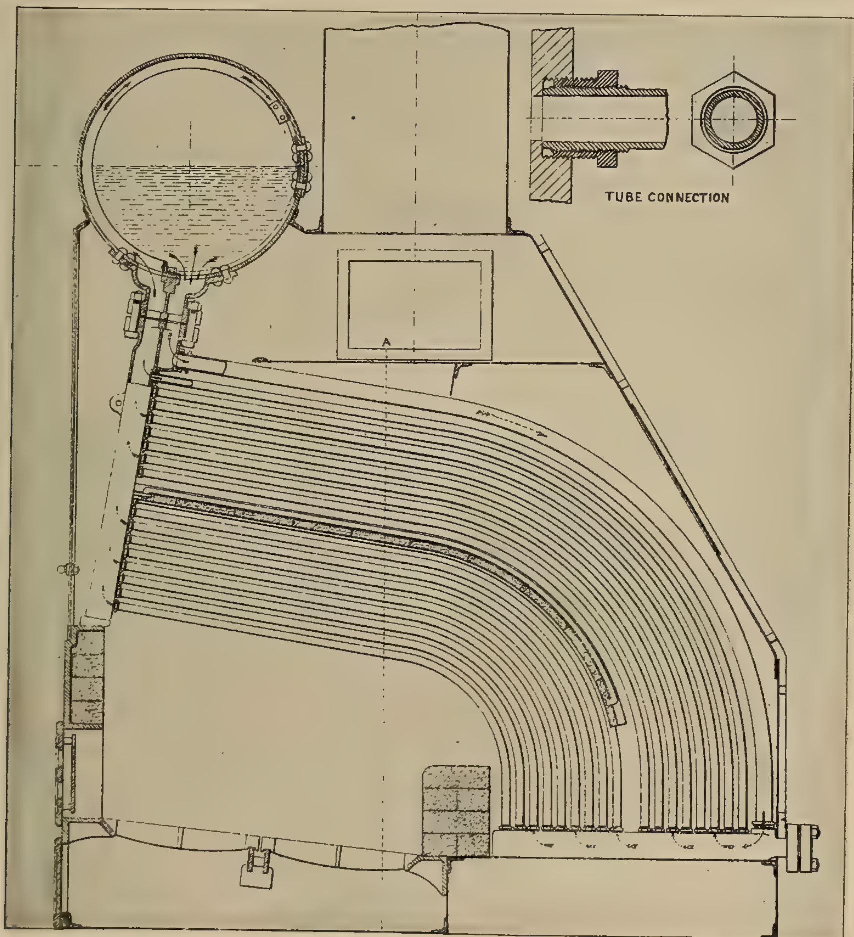
3. *Ability to stand any amount of forcing without injury.*—This does not hold absolutely true for all the water-tube boilers, being only relatively so for those with large tubes. For those with small tubes it does hold strictly. The tests of the *Cushing's* boiler given below show this. After the two tests of nearly twelve hours each, at one-half inch and three inches air pressure, and that of an hour at four inches, there were no leaks and no signs of distress. A Mosher boiler was tested with an air pressure of twelve inches, giving an evaporation of 18.2 pounds per square foot of heating surface per hour into steam of 250 pounds pressure.

Table III.—Data of Performance of Several Water Tube Boilers with Small Tubes.

Kind of boiler	Thornycro't.				Cowles.	Ward.
Where tested	U. S. S. *Cushing*.				On shore.	On shore.
Outside dimensions	10′ × 7′ × 8′				11′ 5″ × 7′ 9″ × 12′ 2″	10′ 3″ diam., 11′ 8″ high.
Grate surface, sq. ft	38 0				47 0	53.0
Heating " "	2,451 0				2,026.75	2,473.5
Weight of boiler, empty, tons	9.00				9.75	11.84
Weight of water, tons	2.00				1.80	2.01
Weight of boiler and water, tons	11.00				11.55	13.85
Duration of trial, hours	2.5	11 5	11.5	1.0	12	12
Air pressure, ins. of water	0.0	0.5	3.0	4.0	2.0	2 0
Steam pressure, lbs	250	250	250	250	160	160
Coal per hour per sq. ft. of grate	7.58	24.12	40.23	66.32	40.19	55.05
Evaporation f. and a. 212 deg. Fahr. per lb of coal	11.90	9.72	8 84	6.51	7.45	7.31
Same per sq. ft. of heat'g surf.	1.40	3.63	5 51	6.70	6.96	8.62
Horse-power on basis of 18 lbs. steam f. and a 212° per I. H. P.	190.6	494.3	750.3	912.4	783.7	1184 6
I. H P. per ton of boiler and water	17.33	44.94	68.21	82.95	67.86	85.53

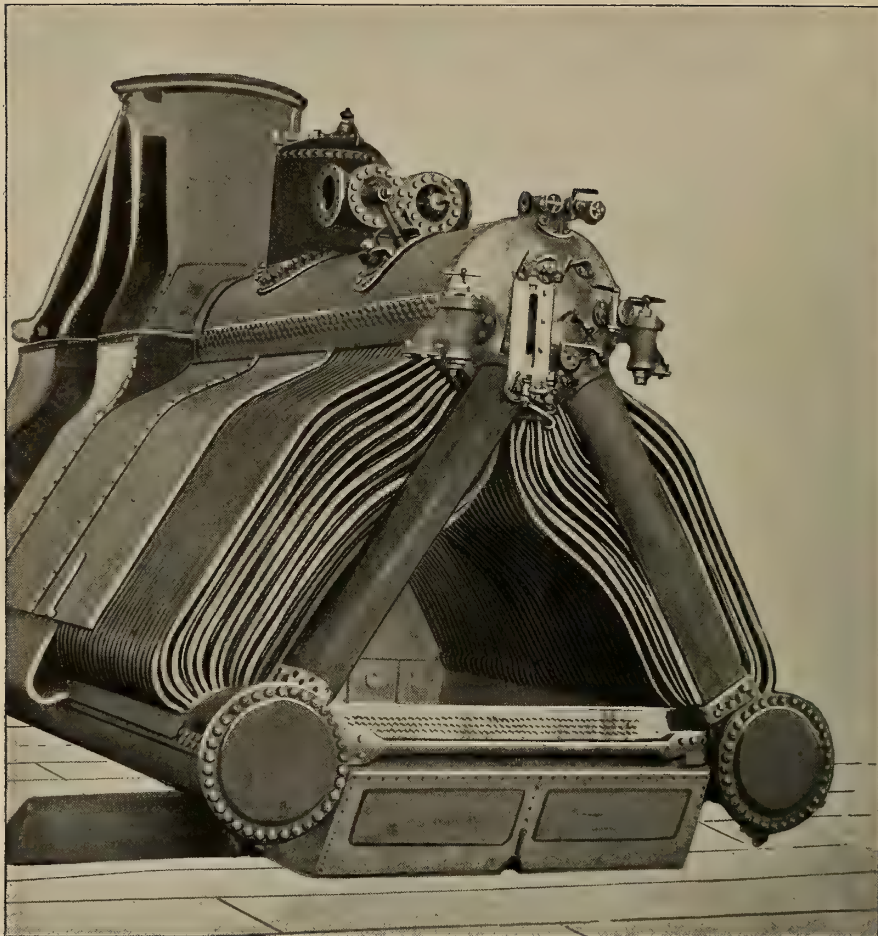
Mr. Mosher says:*—"The object of this test was not for the purpose of advocating any such rates of combustion, but of noting the action of the boiler as to any evil effects arising from such severe treatment. In practice, a boiler may occasionally be driven to this extent if it lies within the power of the fan. The boiler showed no fatigue or effect whatever from this test, every joint remaining absolutely tight." So far as the writer is aware, no such test has ever been applied to a shell boiler, and it is safe to say that such forcing would almost certainly ruin the boiler.

4. *Safety against injury due to sudden changes of temperature.*—With the same reservation as in the last heading this applies strictly. It is due to the elastic structure of the boiler which enables it to expand unequally without distress. Any one who has had any experience with the handling of water tube boilers knows that practically no effort is made to avoid sudden changes of temperature, and doors are opened freely, feed put on suddenly, and anything else that is needed is done with-



BOILER MADE BY THE HAYTHORN TUBULOUS BOILER SYNDICATE, LTD., GLASGOW.

* Proc. Int. Engrg. Congress, 1893, Divn. Marine and Naval Engrg.



A NORMAND BOILER.

out a thought of injury. The writer has had a good opportunity to observe the working of a number of small tubulous boilers in steam launches, the hardest service to which a boiler can be subjected, and he has never yet heard of any trouble on this score.

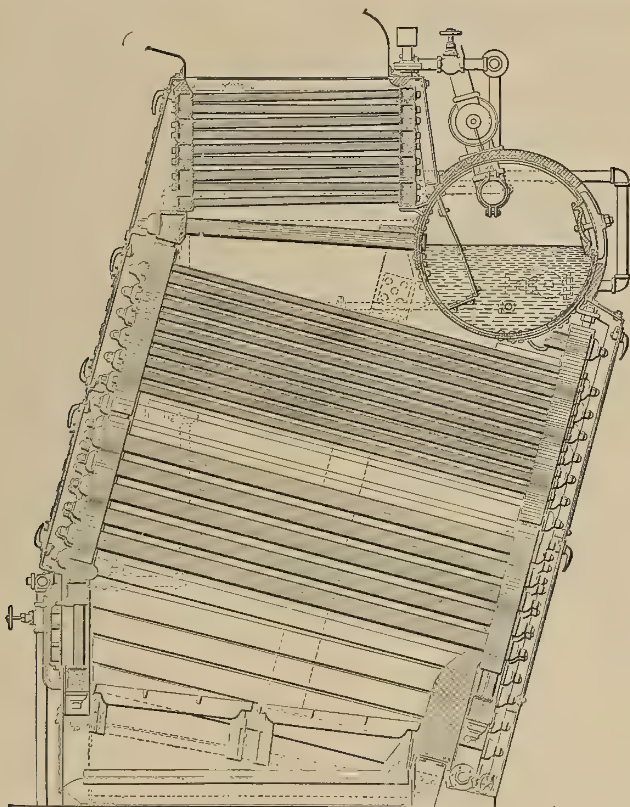
A few years ago, a Towne boiler—launch size—was purposely tested more severely than could ever occur in practice. After working for some hours under strong forced draft and at about 160 pounds pressure, fires were hauled, all doors opened wide, and a stream of cold water from a fire hose played on every part of the boiler until it was cold. In spite of this rough usage, the boiler was not injured in the slightest degree. This quality of being able to withstand what may be called rough "heat usage" is one of the most valuable of those possessed by water-tube boilers.

5. *Rapidity of raising steam.*—This valuable quality in water-tube boilers is primarily due to the small amount of contained water. From the tables already given it will be noticed that one of the *Newark's* boilers, giving 2250 I. H. P. with a little over two inches air pressure, has 22.3 tons of water, while in two Ward boilers, which together would give a little more power, the weight of water is only 4 tons,—an enormous difference. Practically steam

will be raised by the time the fires are well ignited, and it is, doubtless, known to all who take any interest in small yachts or launches that steam is often raised in a few minutes. Secondarily, the rapidity of raising steam is due to the structure of the boiler, which, as already explained, enables it to withstand rapid changes of temperature.

6. *Safety against disastrous explosion.*—It is well understood that the cause of the great disaster when an ordinary boiler explodes is the large amount of contained water at a high temperature, and, as already pointed out, even when the boiler itself is not injured, but a pipe is ruptured, the large mass of water continues to give off steam for a long time. In the water tube boiler, there is much less danger of rupture for the various reasons already given, but if it does unhappily occur, there is so much less water that the only damage will probably be the scalding of the people in the immediate vicinity. In all probability the boiler itself will not be injured beyond the weak part which gave way, and can be repaired.

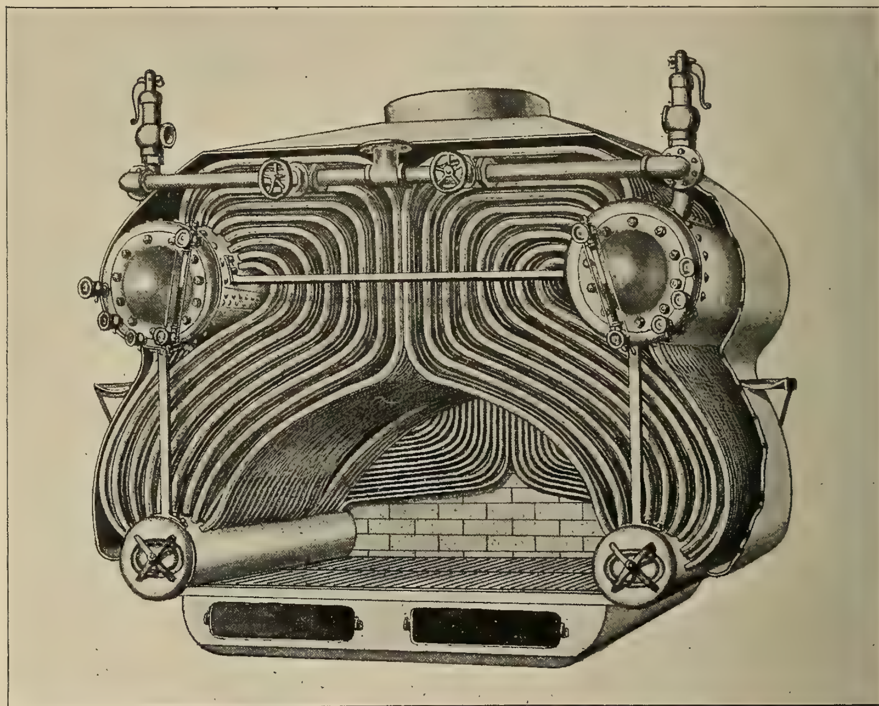
This was illustrated in one case where the boiler of a steam launch exploded, blowing off the whole top of the steam dome and carrying away the smoke pipe, uptake and the boat awning, all of which were above it, but beyond the loss of the dome-top and some fittings on it, the boiler was not injured at all. A new top, uptake and chimney were fitted and the boiler did good service afterwards. It was a small Ward tubulous boiler. None of the people in the boat at the time of the explosion were injured, although two men were right alongside of the boiler.



MARINE BOILER MADE BY THE BABCOCK & WILCOX CO. NEW YORK AND GLASGOW.

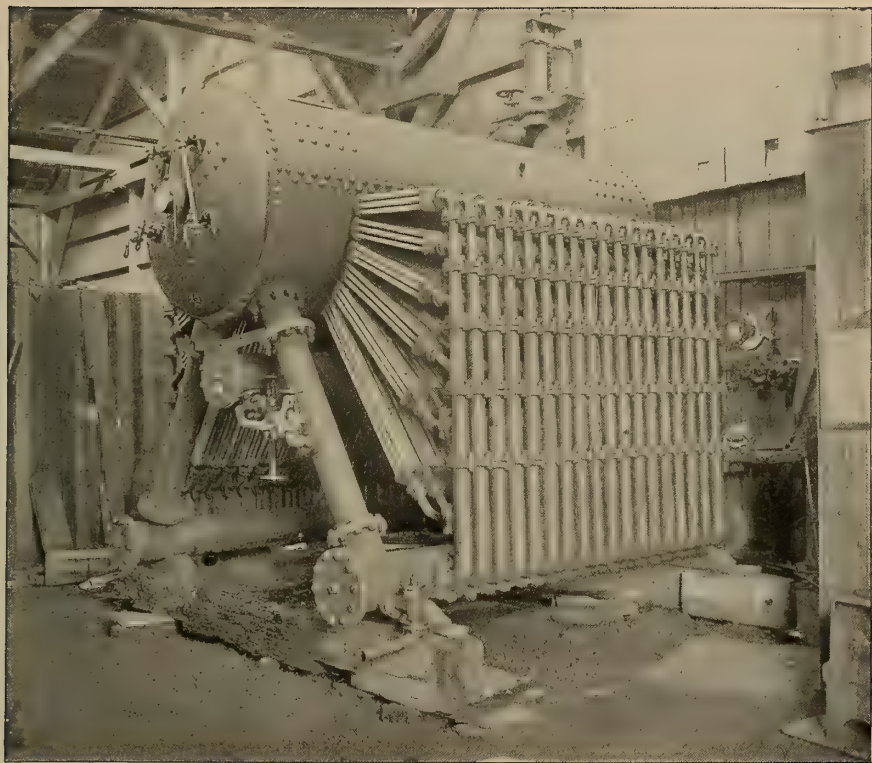
Shortly before this a terrible boiler explosion, in which about fifteen men were killed, occurred at Kiel on a torpedo boat built for the Turkish government. Here it was a large locomotive boiler that exploded, owing to low water, which caused the copper fire box to collapse. Every man in and near the fire room was killed, the boiler was badly wrecked and the deck above it torn up. Of course, it must be recognised that the circumstances were different. The launch boiler was in an open boat and the locomotive boiler in a closed fire room, but even with this taken into account the facts are very instructive. The advantage of a small amount of water in the boiler in case of rupture of a steam pipe will be appreciated from what has already been said of the disadvantage which the shell boiler has in this respect.

7. *Facility for repair and replacement.*—Most of the repairs to a water tube boiler will consist in the removal of leaky tubes, when corrosion has caused holes in them, and the fitting of new ones. Generally, this can be done very readily in all types, although in some it would require the removal of several to get at the defective one. It is to be noted, however, that the tubes are usually so numerous that a number may be plugged without materially reducing the heating surface, and this is generally done for the first tubes that give out.



BOILER MADE BY CHARLES D. MOSHER, NEW YORK.

When the time comes for a general renewal of the tubes, or perhaps replacing the boilers by new ones, the water tube boiler has great advantages over the shell type. In war vessels, the boilers are below the protective deck, which is rarely less than two inches thick in vessels of any size, and in which there are no large openings over the boilers. To get out an old boiler, 15 feet or so in diameter and from 18 to 20 feet long, means the removal of a considerable part of the

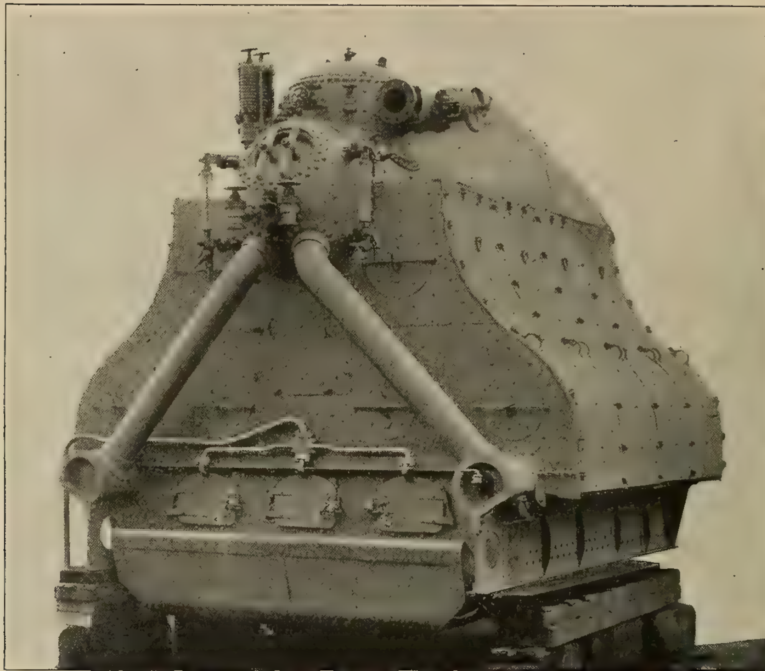


BOILER MADE BY MESSRS. CLARKE, CHAPMAN & CO., LTD., GATESHEAD-ON-TYNE.

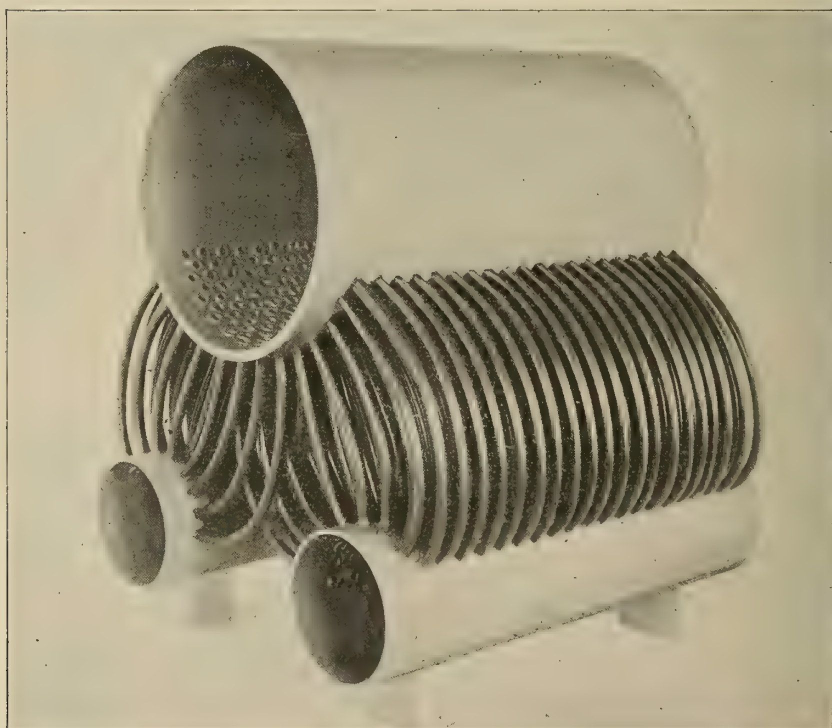
deck. The water-tube boilers, however, consist of a number of small parts, the largest of which will pass through the existing openings. The new boilers can be passed in in parts and erected in place, which is impossible with a shell boiler of any size for the modern high pressures.

This enumeration of the good features of the water-tube boilers would make it appear as though they fulfilled almost perfectly the requirements for a good boiler, and this is nearly the case. There are, however, some inherent disadvantages. In the first place, the water-tube type does not lend itself readily to what might be called concentration. In other words, it is not practicable to build single boilers of as great power as single shell boilers. This can be seen from the comparison of the boilers of the *Newark* and the two French ships, where there are five times as many water-tube as shell boilers for the same power. This means greater expense for boiler fittings, such as safety valves, check and stop valves, gauges and others, and more trouble in tending water, or as Col. Soliani wittily expressed it, at the International Engineering Congress, at Chicago, in 1893, "It is harder to drive twenty ponies than four big horses."

The small amount of contained water, which is a benefit on the whole, nevertheless has some disadvantages. It requires much more care to maintain a steady water level and steam pressure, and in case of the sudden breakdown of a feed pump there is much greater probability of injury to the boiler from overheating, due to low water. This is readily seen if we note that, at the rate of evaporation given in Table III., all the water in the Ward boiler would be evaporated in less than fifteen minutes.



BOILER MADE BY PALMERS SHIPBUILDING & IRON CO., LTD., JARROW-ON-TYNE.



THE CLYDE BOILER. MADE BY MESSRS. FLEMING & FERGUSON, LTD., PAISLEY.

This is, of course, guarded against by duplicate feed pumps and by skill and care on the part of the water tender. A large amount of contained water is a reservoir of heat and acts like a fly wheel on an engine in maintaining a steady steam pressure, so that variation in the amount of feed does not affect the pressure so seriously.

An important defect is that a leaky tube cannot be repaired or plugged without laying up the boiler and allowing it to cool enough to be opened. In case of a bad leak and only one boiler this might, in extreme cases, be very serious. In the fire-tube boilers, a tube can be plugged temporarily without hauling fires or lowering the steam pressure. As a natural result, there should always be at least two water tube boilers in a ship, but, as has been seen, for any considerable power this would be a necessity in any event.

Corrosion of the tubes, or to put it another way, the longevity of the boiler, is a serious matter, and, in the writer's belief, this is the consideration that has prevented a more rapid introduction of the water-tube boiler. Although the tubes are, in many cases, thicker than those of shell boilers and, when new, are greatly in excess of the requirements for strength alone, it must be remembered that they are really the boiler, and not, as in the case of fire tubes, only an important part.

When corrosion once begins to any extent, complete reliance can no longer be placed in the boiler, for a tube is liable to give out then at any time, and, as already stated, a bad leak means the laying off of the boiler. The first impulse is to suggest the use of brass or copper tubes which do not corrode, and this has, of course, been thought of and tried by the talented engineers who are the leaders in the introduction of water-tube boilers. Unfortunately, brass and copper, while non-corrodible, lose a very large percentage of their strength when overheated, and as this is a possibility to be provided for, they are not so well adapted to use in water-tube boilers as iron and steel. After all, as with most things in this world, it is a question of the balance of advantages rather than of absolute perfection, and, if water-tube boilers have a decided superiority in other ways, this matter of corrosion must be accepted as an inevitable defect and every means taken to reduce its effect to a minimum.

It must not be supposed that the life of a water-tube boiler is very short, on account of what has been said. Indeed, experience thus far indicates that the tubes last longer than the fire tubes in ordinary boilers. In several cases within the writer's knowledge water tube boilers on shipboard have been in use five and six years without giving any trouble at all, and, even in the hard service which launch boilers undergo, the tubes have not begun to give out before five years' service. Many fire tube boilers have required a complete outfit of new tubes in three years or less. Data have been published by Mr. Ward, Mr. Roberts and others of water tube boilers which have been used in marine work for more than twelve years without losing a tube. It would seem, therefore, that the extent of corrosion depends to a very large degree on the circumstances under which the boilers are used and the care taken to prevent it, and that with proper care the longevity of water tube boilers will be satisfactory.

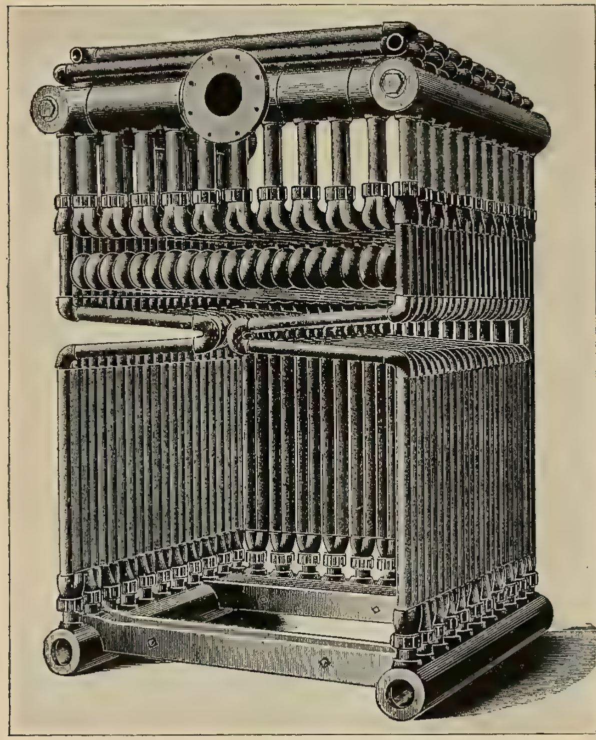
It may be said also that, with all water-tube boilers, but especially with those having small and bent tubes, it is absolutely necessary to use clean, fresh water and to keep all oil and grease out of the boiler. This is true also of fire tube boilers, but as they can be more readily cleaned, salt water may be used occasionally in an emergency and a small amount of grease will not have so bad an effect. All modern ships, however, are provided with evaporators for making up losses of feed water, and with filters for removing grease and dirt, so that all boilers are nearly on an equal footing in this respect.

We have now considered the relative merits of the two types of boilers, and it seems to the writer that the case for the water-tube boiler is very strong,

especially for war vessels. In them, reduction of weight, rapidity in raising steam, and ability to withstand hard usage, in the way of forcing and sudden changes of temperature, make a boiler possessing such characteristics very desirable, and the drawbacks, unless of very great importance, can not offset them. As already stated, the question of corrosion seems to be the most important objection, and this will, undoubtedly, be reduced to relative insignificance.

It is well to remember on this point that not many years ago the shell boiler suffered very severely from this very cause, and it was not until some ten or fifteen years ago that the proper method of treatment was well understood. When a strong incentive exists to carry protection against corrosion even further than at present, the means will, undoubtedly, be found.

Thus far the subject has been here treated to a great extent as if the introduction of water-tube boilers in war vessels was still, in the main, an open question, but in certain classes of vessels they have already become the only type in use. The first instance of the use of water-tube boilers in a war vessel is the French vessel *Voltigeur*, into which Belleville boilers were introduced in 1879. Since that time they have been gradually placed in other vessels of the French Navy, until now there are about thirty so fitted, including a number of the most recent battle ships, the *Charlemagne*, *Gaulois* and *St. Louis*.



BOILER MADE BY THE ALMY WATER-TUBE BOILER CO., PROVIDENCE, R. I.

Belleville boilers have also been adopted in other navies. The Russians have about ten ships with these boilers, including the large armoured cruiser *Rossya*, which is an enlarged *Rurik*. The British Navy is also using them for some of its largest ships, including the two big cruisers *Powerful* and *Terrible*, each of which has 48 Belleville boilers, aggregating 25,000 I. H. P., which, on test, accredited themselves in exceptionally satisfactory manner. The French are giving almost every one of their new water-tube boilers a trial in a war vessel, and at the present time cylindrical boilers have been abandoned for new ships and water tube boilers only are being used. No other country has as yet gone quite so far, although the British Navy is practically employing only water-tube boilers in the new ships which are projected. Thus far, in the United States Navy, water tube boilers are actually in use in only one large vessel, the *Monterey*, which has four large Ward boilers and two cylindrical ones, but the *Nashville* will also have water-tube boilers, as will the *Chicago* when her new machinery is fitted. Other nations have used this

type of boiler to a limited extent. For torpedo boats, water-tube boilers have been used to a great extent ever since the appearance in 1887 of the *Ariete* of the Spanish Navy, built by Thornycroft, which had one of the first of his now well-known boilers. Other builders clung, for a time, to the locomotive boiler, but as already stated, the firm of Schichau, in Germany, about the only one which had not definitely adopted water-tube boilers for all vessels of the torpedo boat class, has now done so. In this connection, credit must also be given to the Herreshoffs, who were among the pioneers of coil boilers and whose work in showing what could be done with very light boilers has been productive of excellent results.

Until recently small-tube boilers have not been much employed, except in small vessels, although the American *Monterey*, the Danish vessel *Gaiser* and the German *Aegir* have such boilers. There are evidences, however, that they will shortly come into more extended use on large vessels. In the British Navy several vessels of the *Barham* class are to have their present cylindrical boilers of from 3000 to 4000 I.H.P. replaced by small-tube boilers of Thornycroft make. The *Proserpine* and *Pelorus*, new vessels of about 2000 tons displacement, have batteries of Thornycroft and Normand boilers, respectively, aggregating, for each ship, 7000 I.H.P. As these vessels are of about the same size as the *Barham* class, while the power of the machinery is about double, a forcible illustration is afforded of the reduction of weight when water-tube boilers with small tubes are used. The French Navy is to have a new triple-screw cruiser, the *Jeanne d' Arc*, of 11,000 tons displacement and 28,000 I.H.P., which will be fitted with Normand boilers. This is the greatest power thus far designed for any war vessel.

To the writer it seems that, if the full benefit of water-tube boilers on war vessels is to be obtained, those of the small-tube type should be adopted. Where those with large straight tubes and closely-braced flat water-legs are used, some of the special advantages of the type are lost and the gain over cylindrical boilers is not very great in any respect. About the only advantage they have over the small tube boilers is the greater facility for cleaning the interior of the tubes, but when proper care is taken to insure an ample supply of clean, fresh water, the interior of the tubes will not need cleaning. As already seen, the use of large tubes does not make a large boiler, and as many or more boilers are needed for the same power as in the boilers with small tubes. Owing to their relatively rigid structure, they cannot be forced to anything like the extent that the small-tube boilers can, and they cannot stand the same amount of rough "heat usage."

BOILER WITH LIQUID FUEL FURNACE. MADE BY THE LIQUID FUEL ENGINEERING CO., EAST COWES, ISLE OF WIGHT.

In conclusion, it may be said that all indications point to the general adoption of water-tube boilers for war ves-

sels,—possibly to the entire exclusion of the cylindrical type, and possibly with a small part of the total power in the older form, as is thus far the practice in the United States Navy. The brief consideration of the question here presented will enable the inquiring reader to understand the reasons for the new order of things.

The tests recently made of the large British cruisers *Powerful* and *Terrible*, both of which, as previously intimated, have Belleville boilers, afford the latest good examples of what may be expected of this type. The results of these tests have been presented, in considerable detail, in a paper read a short time ago before the British Institution of Naval Architects by Mr. A. J. Durston, C. B., R. N., engineer-in-chief of the British Navy. Both vessels develop, as a maximum, somewhat over 25,000 horse-power, and the weights per indicated horse-power, as compared with three recent British battleship designs, are given by Mr. Durston in the following table:—

The weight of machinery of the *Powerful* at 25,000 indicated horse-power, as compared with that of three recent battleships of 10,000 indicated horse-power, their natural draught power, shows the increase of indicated horse-power per ton weight of boilers to be 56 per cent. The weights of auxiliary machinery, such as steering, capstan, electric light, distilling, etc., not directly connected with the main propelling machinery, are not included.

Throughout the trials the behaviour of the boilers, according to Mr. Durston's report, was entirely satisfactory, and they fully realised the expectations of the Admiralty. Practically no defects were developed. When working at the highest powers the decks and casings in the vicinity of the uptakes were heated to an undesirable extent, but when lagging was fitted, as had been originally provided for in the specification, there was no further trouble from this cause.

Ship.	Indicated Horse-Power.	*A.* Weight of Machinery in Engine Rooms.	Indicated Horse-Power per Ton of *A.*	*B.* Weight of Propellers, etc.	Indicated Horse-Power per Ton of *B.*	*C.* Weight of Boilers and Fittings.	Indicated Horse-Power per Ton of *C.*	*D.* Total Weight of Main Machinery and Boilers $=A+B+C$.	Indicated Horse-Power per Ton of *D.*
		tons.		tons.		tons.		tons.	
Average of three recent battleships	10,000 (N. D.)	445.4	22.43	96.6	103.6	726.51	13.76	1268.51	7.9
	12,000 (F. D.)	----	26.93	----	124.36	----	16.52	----	9.46
Powerful	25,000	789.5	31.66	192.72	129.7	1162.05	21.51	2144.27	11.7
Percentage of increase	Compared with N. D.	----	----	----	----	----	56	----	----
	" " F. D.	----	17.56	----	4.3	----	30.2	----	----

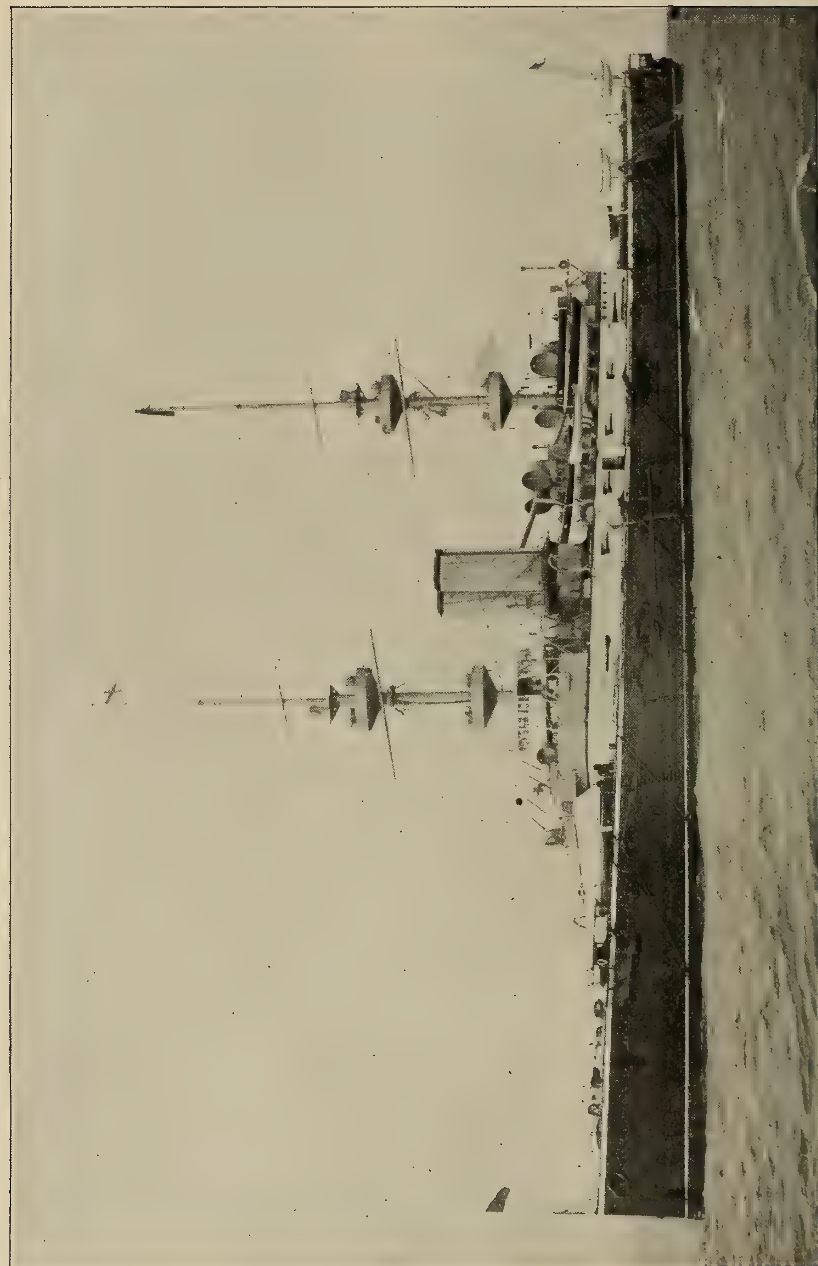
GREAT GUNS ON H. M. S. "SOVEREIGN."

THE NAVAL WEAKNESS OF GREAT BRITAIN.

By Sir Charles W. Dilke, Bart., M. P.

IT is possible now so to write on the navy as to meet with more general agreement than would have been the case a few years ago. Sir John Colomb, Admiral P. H. Colomb and Captain Mahan have taught many men to think upon the subject; and the subsequent writings of a distinguished critic of naval matters,—Mr. Thursfield,—of Mr. Spenser Wilkinson, of Mr. Wilson, the author of "Ironclads in Action," of Mr. Laird Clowes, and others, have cleared the minds even of the general public. The principles upon which the United Kingdom ought to proceed in naval matters have been laid down for her by the greatest naval writer of the United States, and Captain Mahan has defended the course which, to our advantage, he has taken, by his demonstration that the strength of the British fleet is the best security for peace.

During the great war our ancestors had forced upon them a proper treatment of Imperial Defence. From the time of Waterloo down to about 1890 sound principles were almost entirely



THE BRITISH TWIN-SCREW BATTLESHIP "MAJESTIC." DISPLACEMENT, 14,900 TONS. I. H. P., 10,000. SPEED, 17½ KNOTS.

forgotten. No one seemed to remember that our fleet was as much maintained for war as was the Prussian army, and is even more necessary to our existence in the present condition of the world than the armies of France and Germany are to their states respectively.

No one had thought out the seemingly necessary connection between the kind of defence to be offered for our empire and the kind of attack which might reasonably be expected to be brought against it. The naval scares which, from time to time, preceded 1890 had led to ups and downs in expenditure which were entirely indefensible. The naval manœuvres of 1887 to 1889, inclusive, did not teach a lesson sufficiently clearly for the public to learn it; and it is only, I repeat, quite recently that our maritime position has been calmly faced by governments, with a fairly enlightened public opinion at their back.

The official position of both parties in the British State is that we should have for safety an undoubted supremacy of the seas, which is translated in practice as meaning bare superiority as against the dual alliance of France and Russia. Bare superiority has been officially reckoned as being equivalent to equality—a hard saying. But I believe that what is meant is that we may make a large allowance in our own favour on account of the difficulties which attend allied operations, and on account of the superiority of British seamanship—at least over the seamanship of Russia.

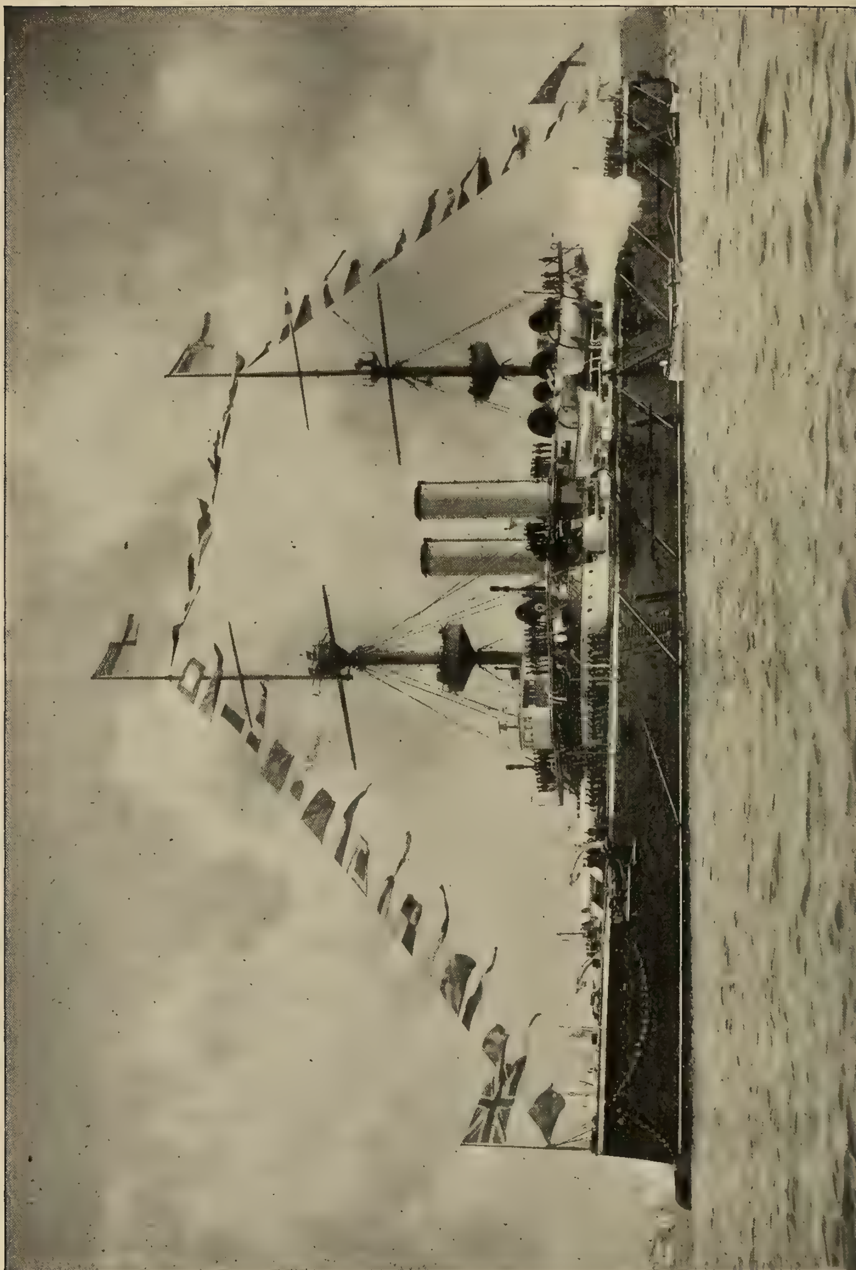
The object which, on a declaration of war, the British naval commander-in-chief, or the Lords of the Admiralty, ought to have in view would be to make our frontier at the enemies' ports and to convert the whole of the seas into British territory. In practice, it is generally admitted that we must fall short of this ideal. To force the enemies' fleets to come out and fight when we are ready for them is not within our power; and to blockade them closely requires a superiority of strength such as we might not possess.

Another element of complication is introduced by the greater rapidity of mobilisation undoubtedly possessed by France, for we are neither inclined to leave the Mediterranean nor to keep there a sufficiently great force as to be safe.

It is probable that some thought has been given in recent times to the problem of how the British Empire should undertake a war, and a Defence Committee of the Cabinet, presided over by the Duke of Devonshire, meets from time to time. But there are many signs which go to show that insufficient consideration has been given to the problem, although that insufficient attention is better than the utter lack of attention of a few years ago. The sums voted by Parliament for military and naval supply, in the course of the last session, added to those paid by the creation of debt in the year 1896–7, added to those spent in India in the last year for which we have the figures, amount to sixty-one millions sterling; and the colonies spending, as they do, nearly two millions sterling in addition, the defence expenditure of the British Empire appears to be, at the present moment, at the rate of sixty-three millions sterling a year. There may be a slight decline next year, but the tendency is, of course, towards increase.

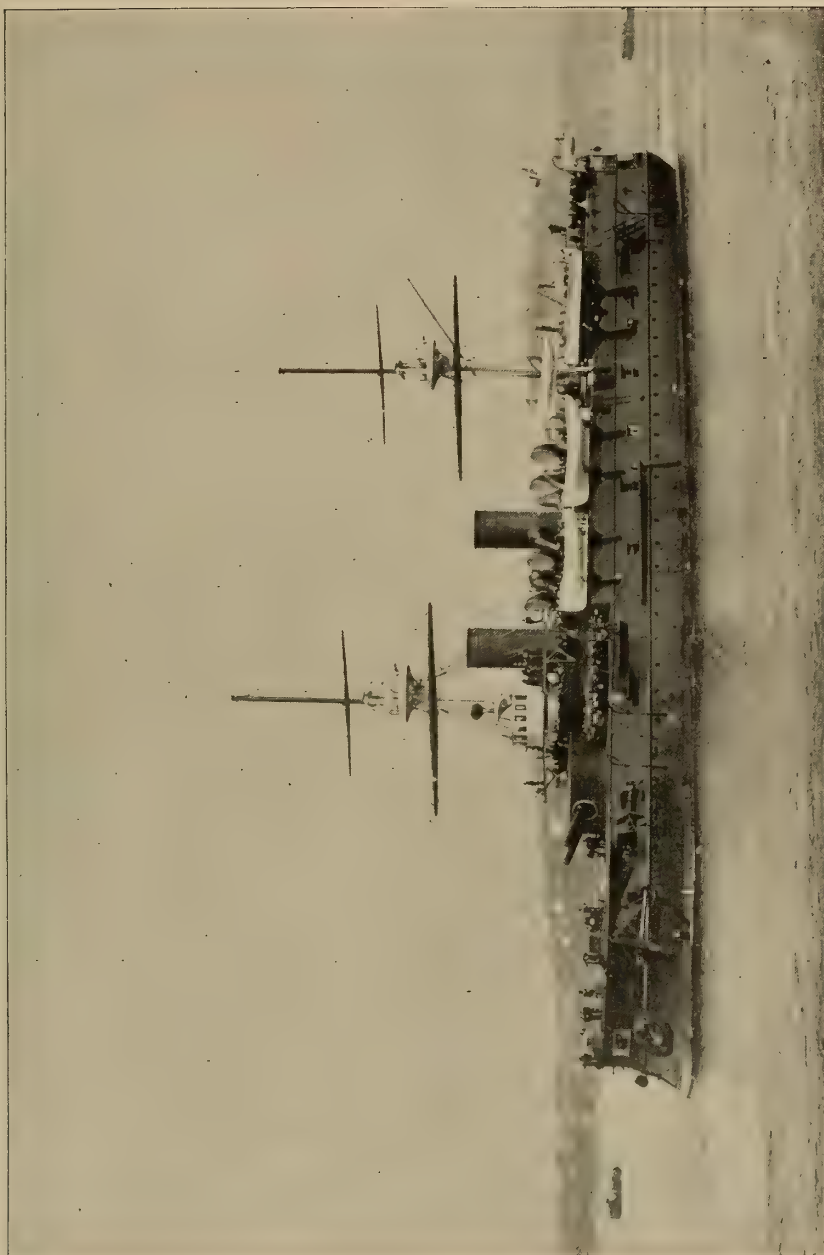
No power in the world has ever spent such a sum on armaments in time of peace, and it is mpossible to say that we get full value for our money. On the other hand, the "increased armaments" protestors are not necessarily right in contending that this expenditure should be decreased, for it may be that we are wiser who think that, while there is room for economy (especially in some branches of the army services), we are not safe without providing more largely than we do for the other services.

I have sometimes asked whether, if a man of business were put at the head of the defences of the British Empire, he could not manage them more efficiently than they are managed, for a less sum than sixty-three millions a year. It may, however, pretty confidently be asserted that the ideal man of business would not take the course recommended



COPYRIGHTED BY MESSRS. SYMONDS & CO., PORTSMOUTH, ENGLAND.

H. M. BATTLESHIP "RESOLUTION," BUILT BY PALMERS SHIPBUILDING & IRON CO., LTD., JARROW-ON-TYNE. TWIN-SCREWS. DISPLACEMENT, 14,150 TONS. I. H. P., 9000. SPEED, 16 KNOTS.



FROM A COPYRIGHTED PHOTOGRAPH BY MESSRS. G. WEST & SON, SOUTHSEA.

THE RUSSIAN TWIN-SCREW BATTLESHIP "NICOLAI I." DISPLACEMENT, 8440 TONS. I. H. P., 8000. SPEED, 14¾ KNOTS.

COPYRIGHTED BY MESSRS. WEST & SON, SOUTHSEA.

THE FRENCH BATTLESHIP "MARCEAU." TWIN-SCREWS. DISPLACEMENT, 10,581 TONS. I. H. P., 12,000. SPEED, 16¼ KNOTS.

by the "increased armaments" protestors, and cut down our fleet; but that he would rather turn his attention to obtaining that cheaper army which might be contrived with due regard to our military needs, and that he might even increase the numbers of our battleships and cruisers.

To protest against increased armaments means that increase in itself is undesirable apart from the question of necessity; and it being admitted that in the case of the navy we come nearer to getting value for our money than we do in the case of land forces, or, indeed, than other powers do, I may, in writing of the navy, put aside this question of cost. If the British taxpayer refuses to pay more money, it is not the increasing expenditure,—that on the navy,—but the stationary expenditure,—that on the army,—which is likely to be cut down.

That the British navy should have an enormous force of cruisers is admitted on all sides. We have almost the whole of the merchant shipping of the world. If insurances are not to go up to prohibitive rates on the outbreak of war, or even on the apprehension of war, the ocean routes must be patrolled, and the fast steamers of the enemy must be watched; while every battle-fleet needs a large force of cruisers as its eyes or scouts, and there is the visiting of coaling stations and the protection of cables also to receive attention.

We have no such cruisers as, for example, the second *Esmeralda*, which belongs to Chili; or even as some of the new cruisers of the United States. We are proud to think that the *Esmeralda* is British-built; but the *Brooklyn*, the *Columbia*, and the other new cruisers of the United States are specimens of what can be built on the western side of the Atlantic.

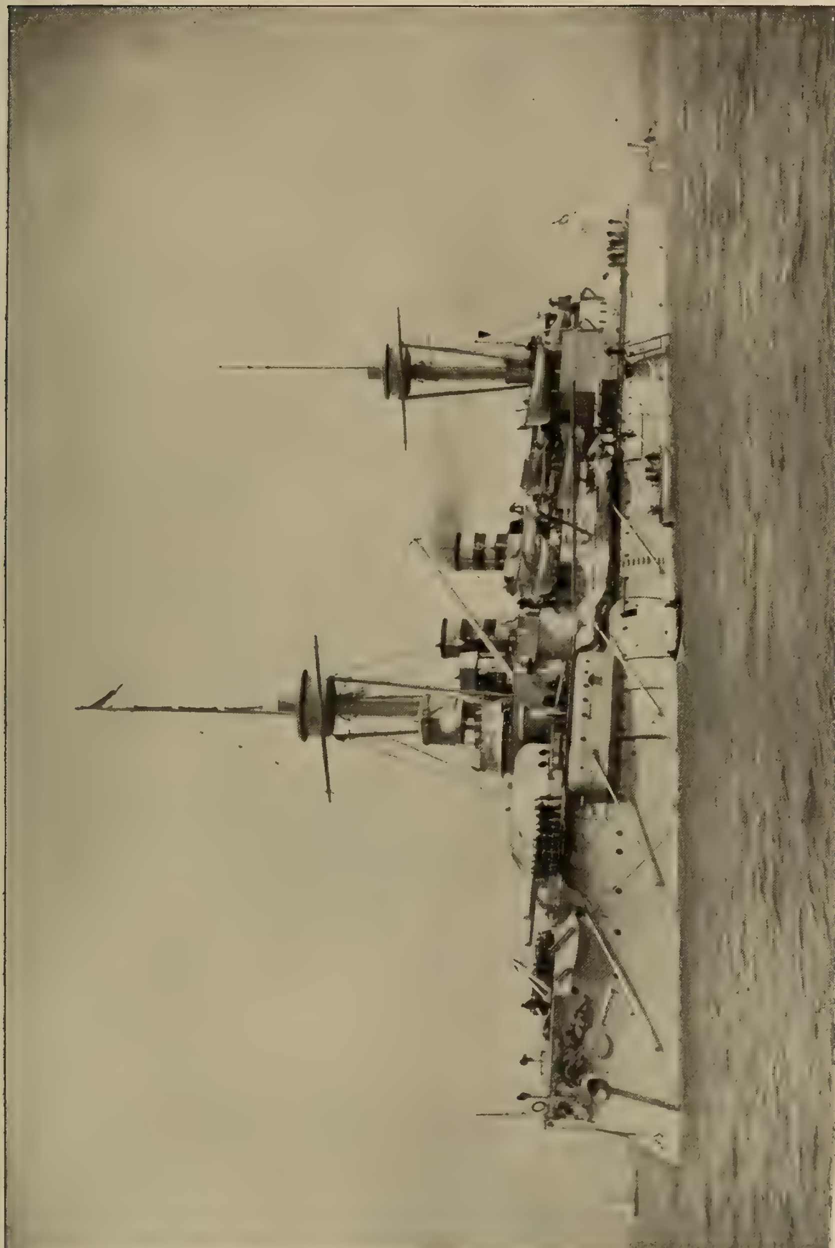
It may, however, be admitted that we have made great strides in recent years in cruiser building, and that our attention for the next two or three years will be directed toward two points which may give us more anxiety. Our ironclad battleships are larger than those of France; and when we count numbers against the French, several coast-defence ironclads are brought into account on the side of France which are inferior in some respects to our own ships. But in order to fight the French in the Mediterranean, or to shut them in if they will not come out to fight, we require ships which can carry coal to steam much greater distances than are needed by the French.

For purposes of blockade, size will not make up for numbers, and yet if we give up blockade we enable our possible enemy, in the event of war, to look forward to escaping from much of the pressure which we could otherwise apply to their policy, and to putting us to enormous inconvenience. For blockade a large superiority of numbers is admitted to be necessary, and we do not possess the necessary superiority in numbers even against France alone, still less as against France and Russia, to be able to blockade their fleets. I am counting France and Russia, because that is the official computation. We are to have superiority over the next two powers; and of these the one is our great naval rival, while the other is the power which is, at the present moment, the most rapidly creating a great ironclad fleet.

Many who admit that we have not the strength to blockade, that the French mobilisation is rapid, and that we might have to meet in the Mediterranean, French squadrons, strengthened by their reserves, with our own fleet not so strengthened, suggest that we should withdraw from the Mediterranean and adopt a policy of masking its entrance.

There is, however, no naval opinion which can be quoted to show that it would be possible to mask the Mediterranean with a lesser force than that which would be needed for the purpose of holding it; and the general naval view is that we shall have to occupy a post from which we can keep touch of such a port as Toulon by means of fast cruisers, and virtually to blockade at a distance; that is, to either shut in or be able to fight at once if the enemy

H. M. BATTLESHIP "RAMILLIES." TWIN-SCREWS. DISPLACEMENT, 14,150 TONS. I. H. P., 13,000. SPEED, $17\frac{1}{2}$ KNOTS.



COPYRIGHTED BY MESSRS. G. WEST & SON, SOUTHSEA.

THE GERMAN TWIN-SCREW BATTLESHIP "WOERTH." DISPLACEMENT, 9842 TONS. I. H. P., 9500. SPEED, 16 KNOTS.

COPYRIGHTED BY MESSRS. WEST & SON, SOUTHSEA.

THE ITALIAN TWIN-SCREW BATTLESHIP "SARDEGNA." DISPLACEMENT, 13,860 TONS. I. H. P., 22,800. SPEED, 19 KNOTS.

come out. But this policy requires a clearer superiority of strength in ironclads than we possess. It will be noticed that I am inclined to assume the rapidity of French mobilisation. I have had the opportunity of watching it and judging it pretty carefully for myself. I compare it with the slowness of mobilisation which our own naval manœuvres annually present, and with the degree in which our mobilisation arrangements were found wanting when the Particular Service Squadron was fitted out as a demonstration against Germany at the beginning of 1896.

I have written down to this point of the Dual Alliance as a possible alliance. My own belief has always been that while the probabilities of peace for a time are very great, in the long run peace will be preserved only if we are in a position to cause such a combination against us, as Germany might create by uniting with Russia, to think twice before it measures its strength against our own.

That we should have to fight the fleets of even other powers in an overwhelming alliance against our arms is, of course, conceivable; but I confess that it does not appear to me to enter into the sphere of the reasonably possible. I can imagine no prospect which would, for example, induce Austria-Hungaria to side with our opponents; and I am sorry to say that I neglect the Italian fleet either as an opponent or a friend—sorry, because I think the Italians would be more likely to be found upon our side than against us.

The Italian people, who have all my sympathy, undertook a task too heavy for their finance when they attempted, at one and the same time, to set up a great Continental army and a magnificent fleet. The result is that both their army and their fleet have, of late, been starved, and their ships are now, for the most part, hopelessly out of date, and would be an encumbrance to our own if we had to take charge of them as allies. Two of their ironclads, their dockyards and naval stations would, however, be a set-off in our favor.

It seems to me, then, that to feel safe and to be certain to be able to preserve peace in the early years of the next century,—to be able, in other words, to pursue our own policy undisturbed, we must have an ironclad fleet of battleships capable of maintaining the command of the sea against the fleets of Germany, France, and Russia. We admittedly have not this, and the figures appear to me to show that we have not the requisite superiority of strength even against the fleets of France and Russia.

That we have not this superiority upon paper is an obvious and undoubted fact, but our friends profess that certain points of advantage at which I have glanced would give it us in practice. To this it may be replied that, on the other hand, there are certain undoubted points of inferiority, to which I shall have presently to allude, as well as elements of doubt which I shall also mention.

It will be observed that I wholly reject the policy based on the argument that our naval insurance ought to be proportional to our shipping at sea. If it so happened that the whole carrying trade of the world was in the hands of the United States, instead of being, as it mainly is, in our own, nevertheless our situation,—with colonies scattered all over the world, with India to defend, with an enormously wealthy mother country and capital, not provided with an army on the Continental scale,—would make it necessary for us, as a matter of very life, to keep exactly as strong a fleet as that which is necessary now. The necessity for the British Empire to command the sea against her possible opponents concerns her national existence more than it does her trade.

If, however, we possessed that undoubted command of the sea, which is, in my opinion, worth paying for as a business policy, even if it were not a necessity of our existence, our trade probably could be carried on in time of war. As matters stand, no naval officer who is not a party politician, will pretend that the fleet is equal to the duties which would be imposed on it

H. M. TWIN-SCREW TURRET SHIP "TRAFALGAR." DISPLACEMENT, 11,940 TONS. SPEED, 16¾ KNOTS. INDICATED H. P., 12,000.

even in a single-handed war with France.

Take the Mediterranean! The best of our naval officers who have served there in recent years are deliberately of the opinion that we should, at the beginning of a war, lose even more through unpreparedness than through inferiority of numbers. In the Mediterranean the French are at home,—with their docks, for repairing ships which might be damaged in an engagement, and with their stores of reserve ammunition.

Malta is in the wrong place for us. The difficulties of maintaining large establishments at Gibraltar are very great. Those of supplying the fleet, and changing ships from home, are greater still. There is an extreme risk of French squadrons combining and attacking our squadrons in detail in the manner which has been illustrated in our own naval manœuvres of recent years.

The question of our unpreparedness connects itself with that of manning, to which I shall presently allude. As matters stand, I fear that we cannot be said to possess the command of the sea; and that when war breaks out we shall be fighting to recover it, while it is difficult to see how we should have the leisure in the first week of war, or the resources, to pour garrisons into our coaling stations and to make the maritime world possible for our cruisers and our trade. The enormous demands which war would make upon the navy would be made suddenly, and there would not be time to bring our vast resources into play to meet them.

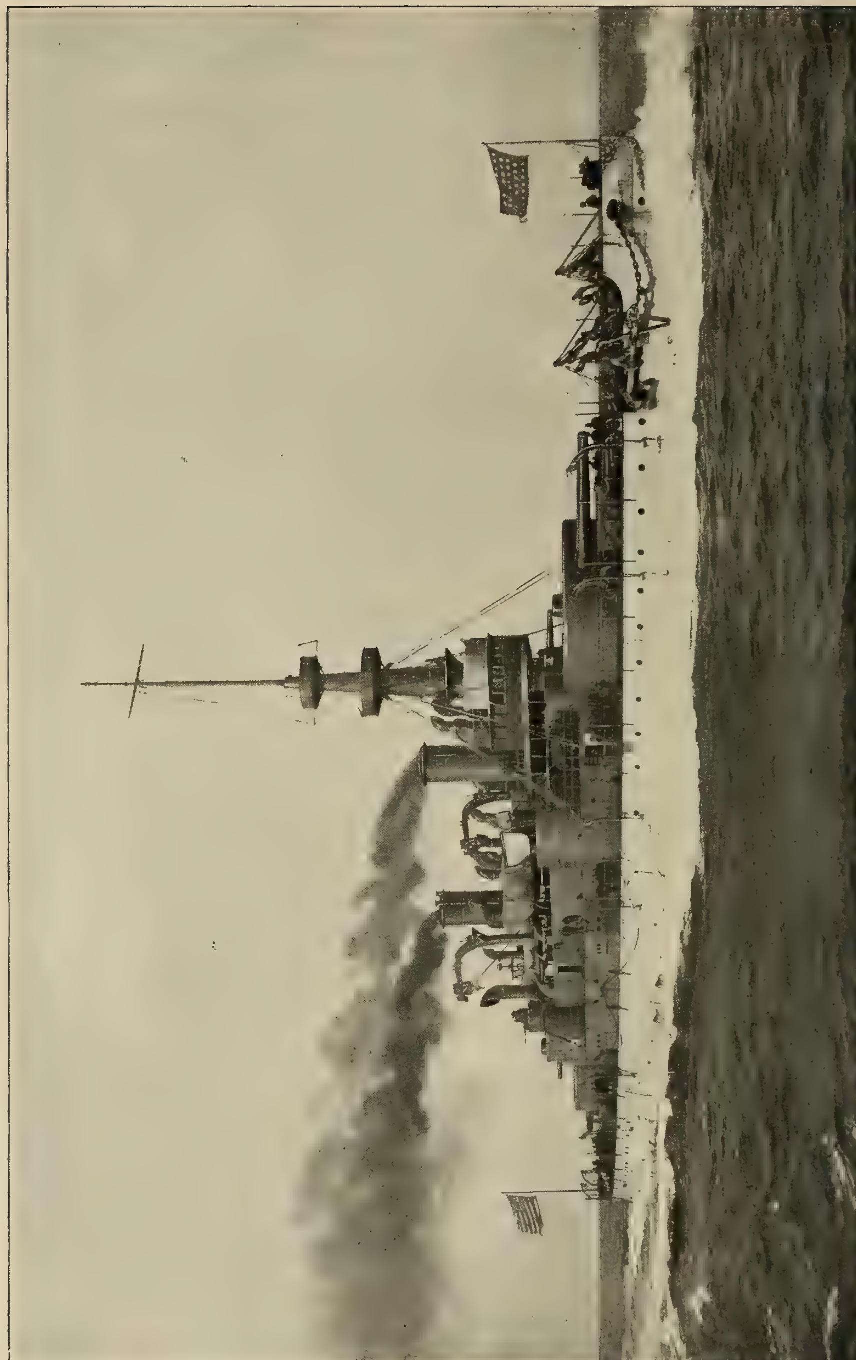
The manœuvres of 1896 have made it clear that the Admiralty have given up the possibility of blockade and have substituted a policy of observation of the enemies' fleets; and given it up, no doubt, because we are not likely to have the requisite superiority of force for a policy of blockade. The policy of observation is a risky policy, which allows of possible junctions of the enemies' fleets, and the adoption of it is a confession of weakness.

I shall not attempt to count numbers in this article, because the question of what we are to count is one upon which there is room for infinite difference of opinion. But no one can carefully read either the excellent recent book of Mr. G. W. Steevens, "Naval Policy," or the return "Navy, Fleets of Great Britain and Foreign Countries," recently issued by the Admiralty upon my motion, without discovering that France and Russia together are building ironclads as fast or faster than we are, and that a clear superiority over them, which is not claimed for us at present, cannot be established as regards the next few years.

An effort will be made in Parliament this year to induce the Government to immediately lay down fresh ironclad ships; but it is possible that, as the Chancellor of the Exchequer seems to have made up his mind that there is to be a diminution in the shipbuilding vote, this attempt will not succeed. We have hitherto plumed ourselves upon the fact that we could build far more rapidly than could other powers; but France has recently increased her pace both in building and in completion, and this material fact has not yet been grasped either by the public, or, apparently, by our own naval advisers.

In addition to deficiency in those battleships, the numbers of which are vital to us, there are, as I have said, some points of doubt which are disagreeable to contemplate. The French carry high-explosive shells in all their ships, and they count upon the rapid destruction of the unarmoured and of the lightly-armoured portions of our battleships by means of these shells in an engagement, and believe that the poisonous fumes which the shells emit would render large portions of our armament unusable.

Our own sailors think high-explosive shells unsafe, and the fifty H. E. shells per ship that are now carried by our Channel squadron (and there are none, I believe, carried by any of our other ships) seem to have been taken on board to satisfy public opinion. I am told that the fuses are at the wrong end, so that they are useless for armour



THE U. S. BATTLESHIP "INDIANA." TWIN SCREWS. DISPLACEMENT, 10,231 TONS. I. H. P., 9000. SPEED, 16 KNOTS. BUILT BY THE WM. CRAMP & SONS SHIP & ENGINE BUILDING CO., PHILADELPHIA.

piercing; because we have found that we cannot safely use them with the fuses at the right end. The French say that they can so make use of theirs.

We do not appear to be in possession of shells of the same construction as the French shells which are carried in the tropics in refrigerating chambers. Our officers generally think our own H. E. shells both useless and dangerous, and probably in time of war would drop them overboard. This is not the case with the French, and, therefore, presumably the French have a safer and better pattern of melinite shell than that which we have been able to supply; and it must be remembered that the French communicate to the Russians the whole of their inventions, and even manufacture, when necessary, for the Russian Government.

French authorities state that melinite is safer than picric acid, and this, which is the basis of a common yellow pigment, is carried everywhere. In the Report on the French naval budget for 1897 it is admitted that the French navy and the French army hold different views as to the power of piercing thin steel armour with H. E. shell. The navy contend that they can at least explode their shells within the plate, thus making a big hole, and that all behind will soon lie open and be swept by a fire in the explosions of which no man can breathe.

Another element of doubt concerns that telegraphy upon which all our arrangements in war, with our complicated trade and Empire, would depend. The author of the Prize Essay of the Royal United Service Institution has shown the incalculable importance of submarine cables, and especially the risk to ourselves of loss by false news until we have our chief cables in our own hands. We have not yet, however, even our own cable line to Gibraltar,—essential as at least that line is to all our services in time of war.

I have left for the last one of the most important of all considerations which concern our maritime position,—namely, that of men. There are some, like Lord Charles Beresford, who, attaching, as they do, overwhelming importance to our having a sufficient strength, and believing, as they do, that we have not that strength at present, nevertheless believe that our attention should be first called to our deficiencies in men, because, as they say, "Of what use to build ships when we have not at present even enough men to man the ships that we do possess?"

By taking almost all the disposable men immediately to be obtained from the reserve, we can send to sea all our ships of the first line. It must be remembered, however, that this leaves us with an increasing difficulty of obtaining trained men to man the ships which will be brought into use as the ships of the first line are destroyed. Our reserves themselves are not trained seamen, while the reserves of the Continental powers largely consist of men who have served their three years at least on the ships of the navies of the various powers. We are short in bluejackets; we are short also in lieutenants, having, indeed, fewer than has France alone. We are short in engineers and stokers, and our mobilisation arrangements do not apparently get over the difficulty that our ships of the second line would have crews which could not be expected to fight their guns.

Mr. Goschen is pledged to grasp this subject in the course of 1897, and it is to be hoped that the proposals which he will make will be such as to commend themselves to Lord Charles Beresford and his friends. I have myself more hope that progress will be made in the direction of proper arrangements for the manning of our ships than I have of our making up our deficiencies in battleships, and I am, therefore, the more inclined to direct attention to this point.

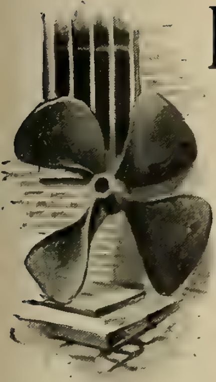
The sacrifices which are asked from us in time of peace are, no doubt, great; but it is impossible to draw that sharp distinction between time of peace and time of war which was possible in the old days. The view once was that the Treasury should hold a tight control over the national finance in time of peace, and give the services all they

asked for in time of war. But the British navy will have to fight its next great naval war with the resources that it possesses in time of peace. If we can stand the strain of the first few weeks of war we shall come out triumphantly at its close. It is readiness to fill up our coaling stations with coal and garrisons, to patrol our trade routes, to watch our enemies' commerce destroyers and cruisers, and to fight, blockade, or mask their ironclad fleets in the first few weeks of war, that is essential to us.

Our fathers in 1813 spent far more money on their fleets than we do even now. They had over 147,000 men serving under the Admiralty at that time, although in those days, in addition to the forces, large numbers of troops (and not marines) were employed upon expeditions sent by sea. They had an enormous reserve of merchant seamen of British race. The British merchant-seamen of our day are dwindling in their numbers, and whatever steps Mr. Goschen may take in 1897 towards supplying the deficiencies of our fleet, he will not, I fear, succeed in rapidly regaining for the country that confidence in the supremacy of her navy which she desires to hold.

THE MODERN MARINE ENGINE.

By Charles E. Hyde, M. Am. Soc. M. E.



IN considering the development of the marine engine, it has long been the custom to regard the advent of the compound engine, which may be said, approximately, to have occurred in the early sixties as the beginning of an epoch, to look upon the compound engine as the modern engine and John Elder as its prophet.

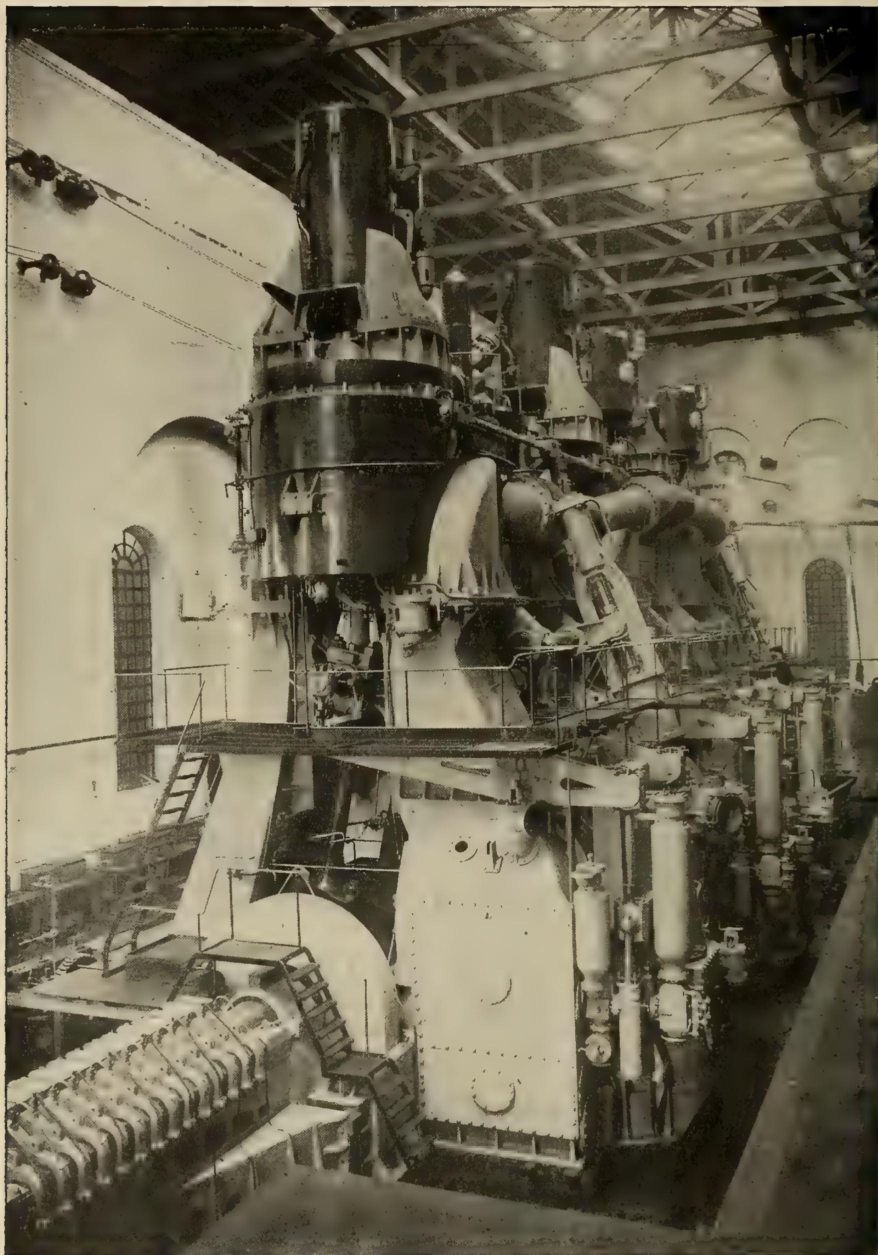
It may well be questioned now, however, when we see the numbers of the compound engine rapidly diminishing,—superseded, except in special cases, and in very small vessels, by other types, whether it is not time to relegate it to the obscurity of ancient things and to take a new point of departure, which naturally connects itself with the first distinctly successful triple expansion engine and with the name of the late Alexander Carnegie Kirk, to whose keen perception and bold grasp of engineering problems we chiefly owe the successful introduction of that type of marine engine.

It must not, however, be forgotten that the first breach in the wall of conservatism and prejudice was made by those who, discarding the single-cylinder engine, with its low boiler pressure and slow rotative speed, adopted steam of higher pressure, its use in two successive cylinders, and higher piston speed, and none of the magnificent steamships of the present day can be more significant of progress than were the *Italy* and *Egypt*, which, in 1869 and 1870, steamed out of the Mersey, —the first compound engine ships built for the transatlantic service.

It must have been no small achievement to overcome at once, in such measure, the capitalist's natural distrust and the sailor man's chronic opposition to novelty. We have an echo of the battle in the statement once made by Charles Randolph, the late partner of Mr. Elder, that the latter "on several occasions proposed to give up the making of the combined (*i. e.*, compound) engine and go back to the older, but more wasteful, form of engine, rather than continue to combat the difficulties and uphill work of bringing it into general practice." Any engineer of the present day who has taken active part in the introduction of triple and quadruple expansion knows something of the depth of discouragement there indicated.

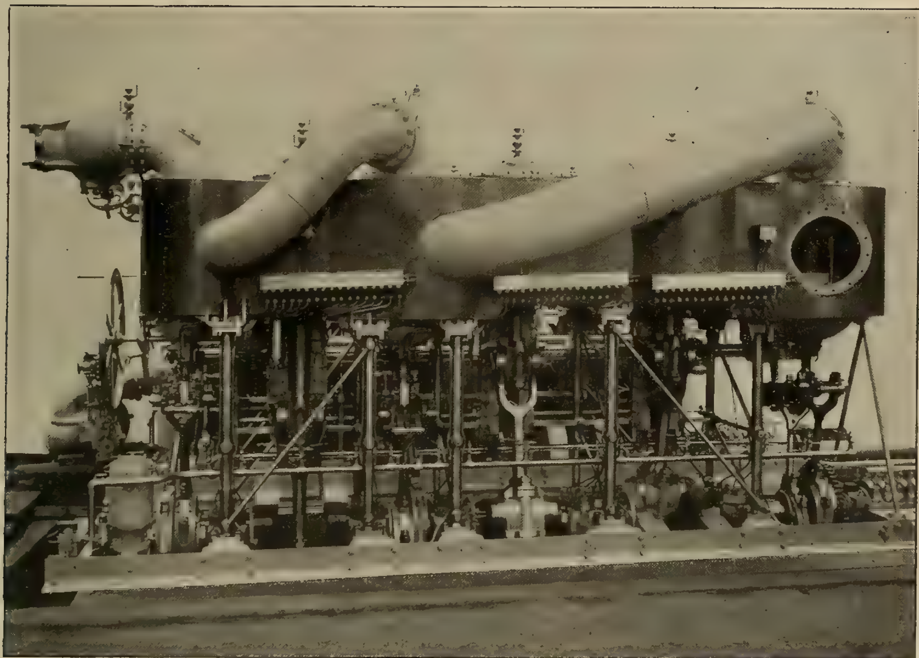
The writer may, perhaps, in connection with this, be permitted to give an incident coming to his knowledge about ten years ago. An old established company, operating a line of low-pressure, single-engine steamers, having New York as one of its ports, had reached a point in its development where it became necessary to provide a new and larger boat.

The problem of hull design, including deck and joiner work arrangement, was easily differentiated from the boats then in use by conference among the captains, officers and other officials of the line. The question of motive power, however, once so easily decided, had become difficult, for since the old boats were built, the compound engine had come about and was then actually found to be in general use, and one of the most influential and enterprising of the directors of the company, who, it may be mentioned, had never been to sea and had never run an engine, had



THE TWIN SCREW ENGINES OF THE STEAMERS "CAMPANIA" AND "LUCANIA" OF THE CUNARD STEAMSHIP CO. I. H. P., 30,000. FOUR CYLINDERS, 37 IN. IN DIAM.; 2 CYL., 79 IN.; 4 CYL., 98 IN. STROKE, 5 FT. 9 IN. BUILT BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD., GOVAN, GLASGOW.

even heard that a man in Scotland had had the temerity to add a third cylinder and to state that a saving in fuel had been effected thereby. This rumour*, though in itself regarded with scant respect, seemed, in some way, to infuse the board with that degree of recklessness that they were disposed to favourably consider fitting the new steamer with a compound engine, and from that time the opinions of the "engineer," their designing and constructing engineer was one of the younger members of the fraternity who had seen the "handwriting on the wall" and impatiently regarded the compound engine as a thing of the far-back past and believed himself charged with a mission in the introduction of its successor. He was determined that the new steamer should be fitted with triple expansion machinery, embodying the results of



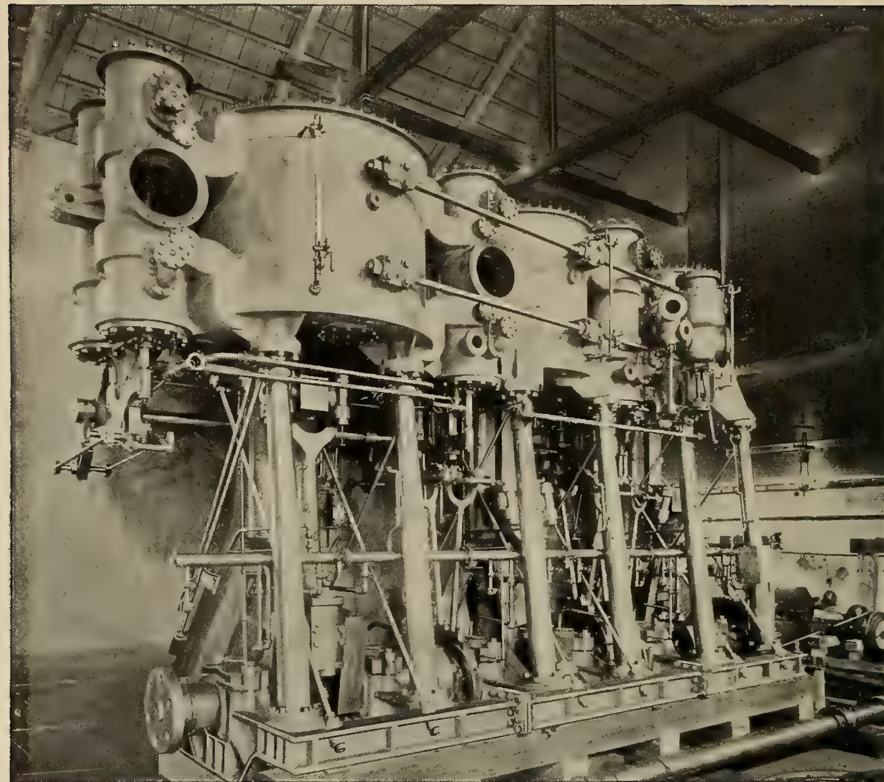
THE ENGINES OF A TORPEDO BOAT DESTROYER. BUILT BY PALMER'S SHIPBUILDING AND IRON CO., LTD., JARROW, ENGLAND. CYLINDERS, 18, 27½ AND 42 INCHES IN DIAMETER. STROKE, 18 INCHES. I. H. P., 4000.

who was to be promoted to the new from one of the old steamers and who had been an active and persistent advocate of the single engine, were set aside.

Upon reaching this advanced position the advisory services of an ex-steamboat engineer, formerly connected with the line, were enlisted, and a consultation as to details was held with the proposed builders of the ship. It chanced that the most recent experience. This position, taken by the young man, aroused, at once, the united opposition of all the engineers and ex-engineers connected with the steamship company to whom the unfamiliarity of the idea was enough to condemn it uninvestigated and without qualification, and who received aid and comfort in making cause against the innovation from the technical staff of a rival engineering establishment which was still going along serenely in the old way.

Every difficulty or mishap that had

* There were at this time in sea service about sixty steamers having triple expansion machinery, the entire success of many of which might easily have been ascertained by any one interested.



TRIPLE EXPANSION ENGINES OF THE U. S. BATTLE SHIP "MASSACHUSETTS." WORKING PRESSURE, 160 LBS. TWIN SCREWS. 4500 H. P. IN EACH ENGINE. BUILT BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHIA.

been experienced in the use of the triple-expansion engine was eagerly searched out, and every possible, and some impossible, objections were marshalled to keep out the intruder. Stockholders were besought to remonstrate with the directors against risking their money in experiments. The horrors of high steam, with the supposed accompaniment of enormous repair bills were duly worked, and the catalogue of the objections put forward with the utmost insistence and positiveness by these practical men would now be amusing indeed.

One argument which was regarded as unanswerable and final was that the ship would be involved in frequent collisions in passing through the crowded harbour of New York owing to the impossibility of handling an engine of so many parts with sufficient promptness to avert these accidents. The old boats were reversed, when they did not stop on the centre, by about a dozen turns of a large hand wheel actuated by two strong men. It is needless to say that the proposed design contemplated a modern steam reverse gear which a child could operate instantly with one hand.

The question was settled finally with the substantial aid of the before-mentioned enterprising director in favour of the triple-expansion machinery, followed by results so eminently satisfactory to all concerned that the new ship has been followed by three others of similar kind, the question never being raised by any one as to the type of machinery to be used.

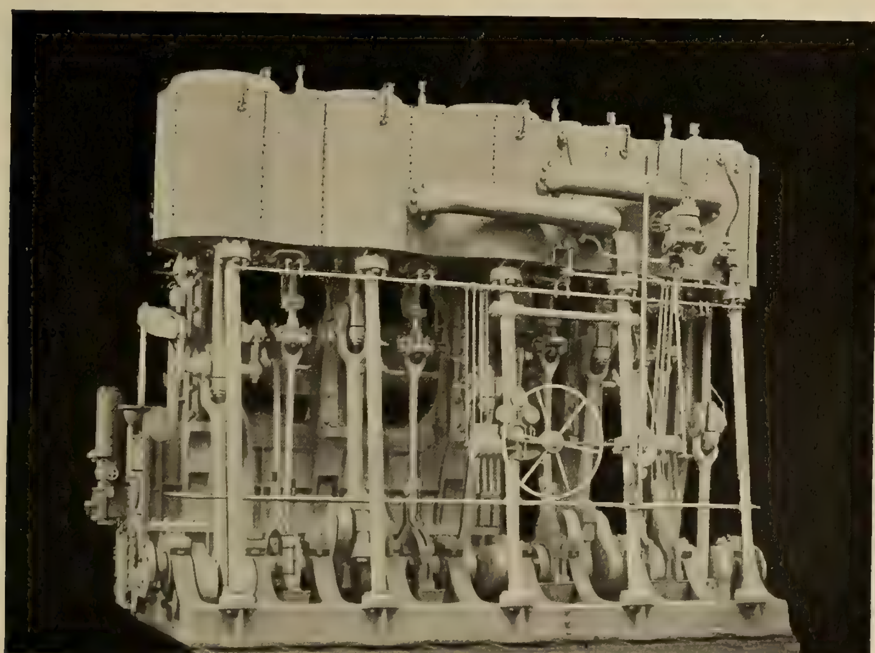
While it is, doubtless, true, as a rule, that the so-called practical marine engineer hangs back in the traces when any innovation is proposed which will modify the familiar routine of his duties

or change the aspect of his surroundings, yet it should be said, as equally true, that the new order of things once being installed, its success is often promoted and made lasting by the results of his critical observation and operative skill.

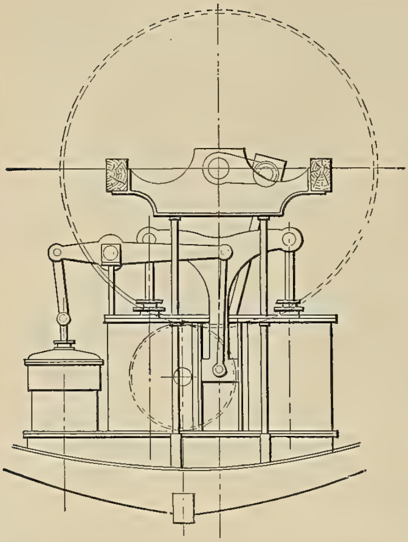
The steamship *Italy*, before alluded to, was built for the National line in 1869 by Messrs. John Elder & Co., now the Fairfield Shipbuilding and Engineering Co., of Govan, Glasgow. She was 385 feet long, 42 feet beam and 38 feet 1½ inches deep to the spar deck. She had a vertical, inverted, direct-acting engine with two cylinders, 60 and 96 inches in diameter by 4 feet stroke, fully steam jacketed; a surface condenser, and three double-ended boilers, 12 feet 3 inches in diameter by 16 feet 6 inches long; working pressure, 60 pounds. She was engaged in the transatlantic service successfully for many years.

With the adoption of the two-cylinder compound engine and surface condenser in ocean navigation the consumption of coal was brought down from about three pounds to about two and one-quarter pounds per indicated horse-power per hour, and this advanced state of things seemed, for a time, so satisfactory that no considerable measures for improvement were attempted. Although much ingenuity was displayed by different builders in attempting to get the best arrangement of cylinders and working parts, some of which, in connection with some of earlier date, are outlined in the diagrams on pages 446, 447, 448, 450, 451 and 453, the vertical inverted, fore and aft and-aft arrangement was generally reverted to as giving the best account of itself in actual service. As steamers increased in size, and as higher speed, with consequent increase of power, was demanded, the low-pressure cylinder became of such great size as to be difficult to make, and the moving parts were found to be heavy and unwieldy.

The *City of Berlin*, built in 1875, developing 4800 indicated horse-power, had cylinders 72 and 120 inches in diameter by 5 feet 6 inches stroke. The



QUADRUPLE EXPANSION FIVE-CRANK MARINE ENGINE. BUILT BY MESSRS. WILLIAM GRAY & CO., LTD., WEST HARTLEPOOL, ENGLAND. I. H. P., 1600.



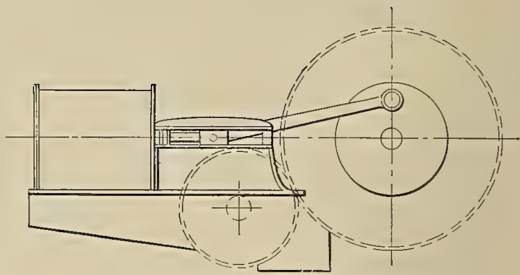


FIG. 2. RENNIE. TWO CYLINDERS, 50⅛ IN. DIA. 3 FT. STROKE.

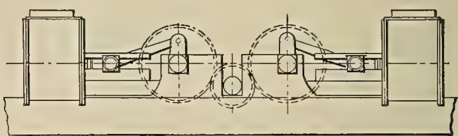


FIG. 1. MAUDSLAY, 1840. FOUR CYLINDERS, 40⅛ IN. DIA. 4 FT. STROKE. 200 H. P.

FIG. 3. SEAWARD. FOUR CYLINDERS, 62 IN. DIA. 3 FT. 6 IN. STROKE. 620 H. P.

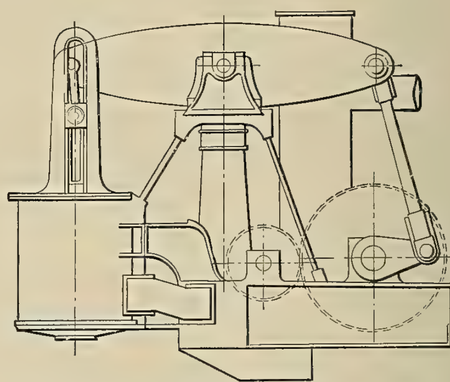
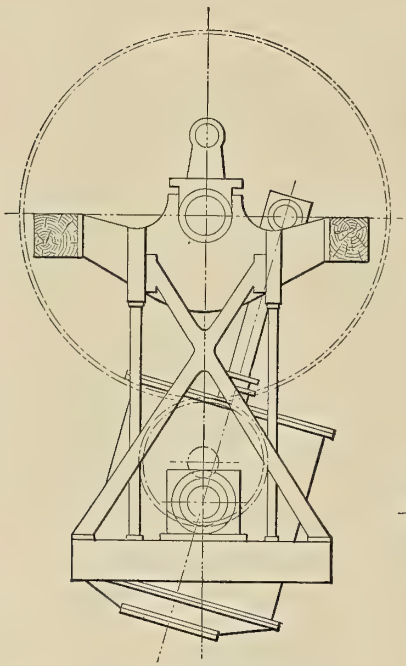


FIG. 4. TOD & MAC GREGOR, 1850. S. S. "CITY OF GLASGOW." TWO CYLINDERS, 66 IN. DIA. 5 FT. STROKE. 310 H. P.



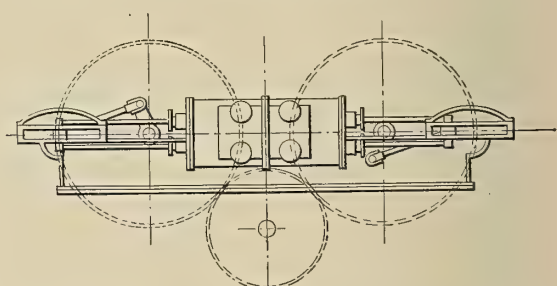


FIG. 5. S. S. "GREAT BRITAIN," 1843. TWO CYL., 82 IN. DIA. 6 FEET STROKE. 500 H. P.

FIG. 6. MAZALINE. TWO CYLINDERS, 38⅛ IN. DIA. 3 FEET STROKE. 120 H.P.

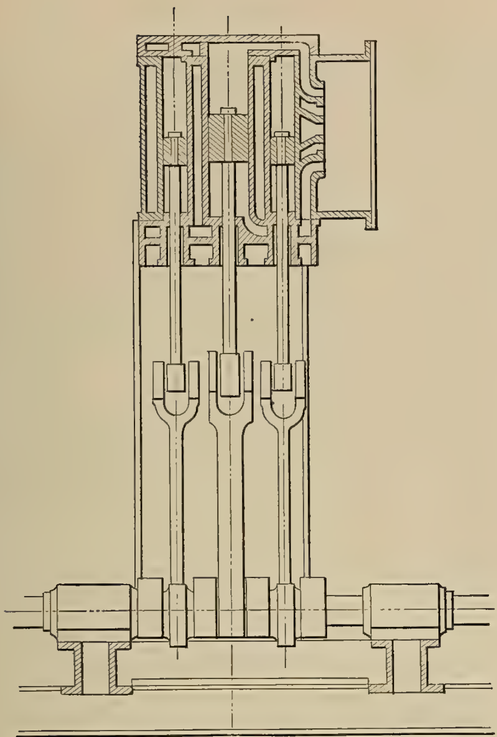


FIG. 7. D. THOMSON, 1860. 35 H. P.

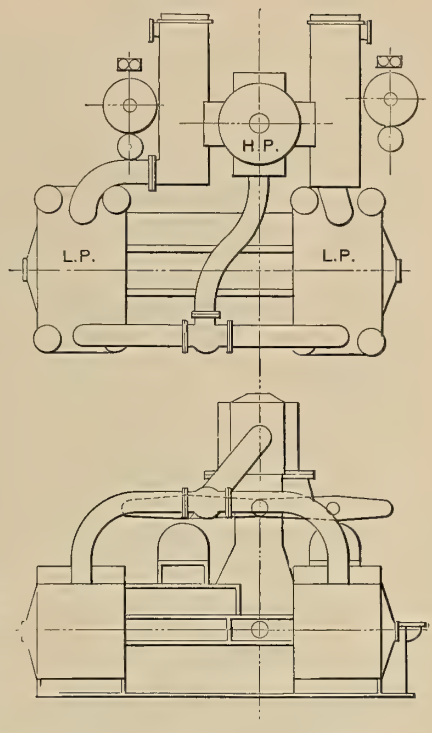


FIG. 8. S. S. "MONTANA," 1872. ONE H. P. CYL., 60 IN. DIA. TWO L. P. CYL., 113 IN. DIA. 3 FT. 6 IN. STROKE.

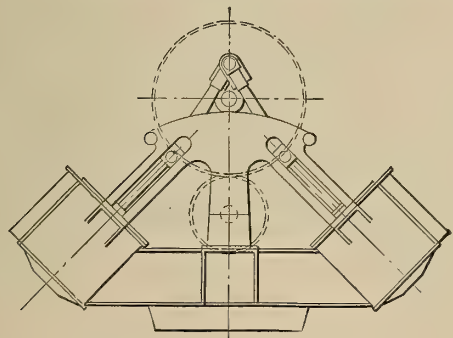


FIG. 9. J. & G. THOMPSON. TWO CYLINDERS, 41 IN. DIA. 3 FT. STROKE. 110 H. P.

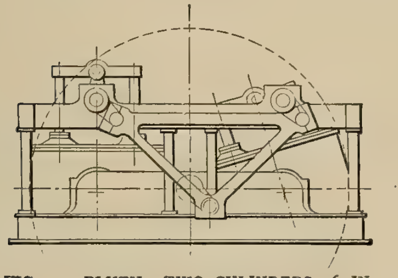


FIG. 10. BLYTH. TWO CYLINDERS, 76 IN. DIA. 2 FT. 9 IN. STROKE. 450 H. P.

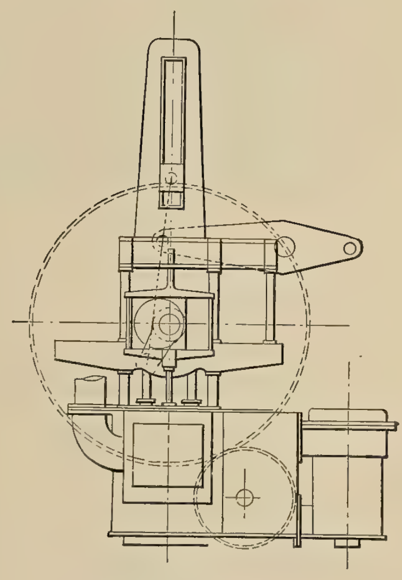


FIG. 11. SMITH & RODGER. TWO CYLINDERS, 40 IN. DIA. 3 FT. STROKE. 100 H. P.

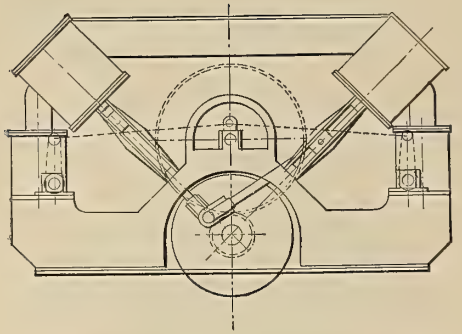


FIG. 12. STOTHERT. TWO CYLINDERS. 28 IN. DIA. 21½ IN. STROKE. 100 H. P.

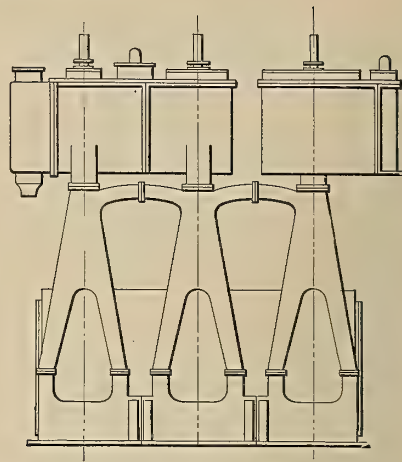


FIG. 13. NAPIER, 1882. S. S, "ABERDEEN."

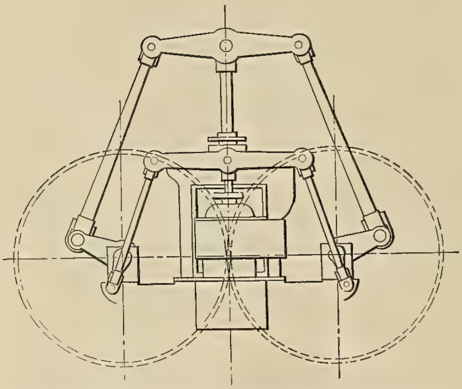


FIG. 14. STIELER. ONE CYLINDER. 15.94 IN. DIA. 19.68 IN. STROKE. 16 H. P.

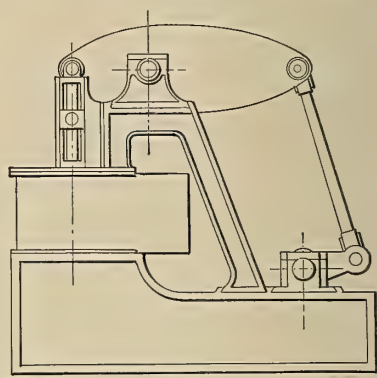


FIG. 15. WHITELAW. TWO CYLINDERS, 66 IN. DIA. 2 FT. 6 IN. STROKE. 500 H. P.

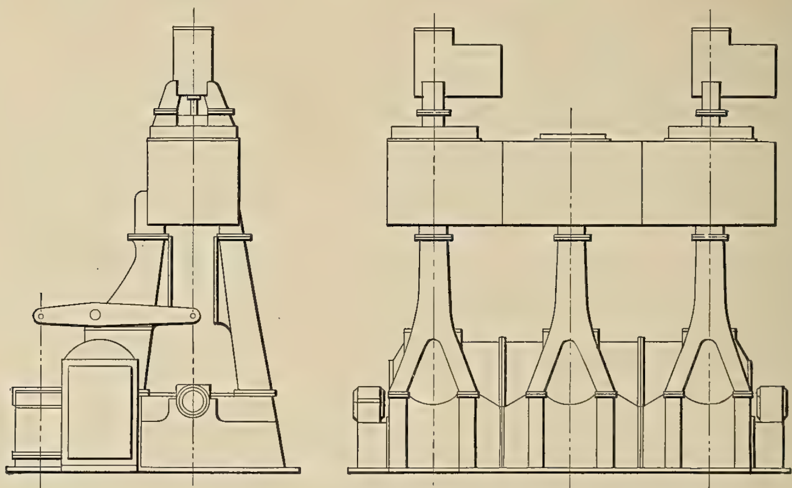
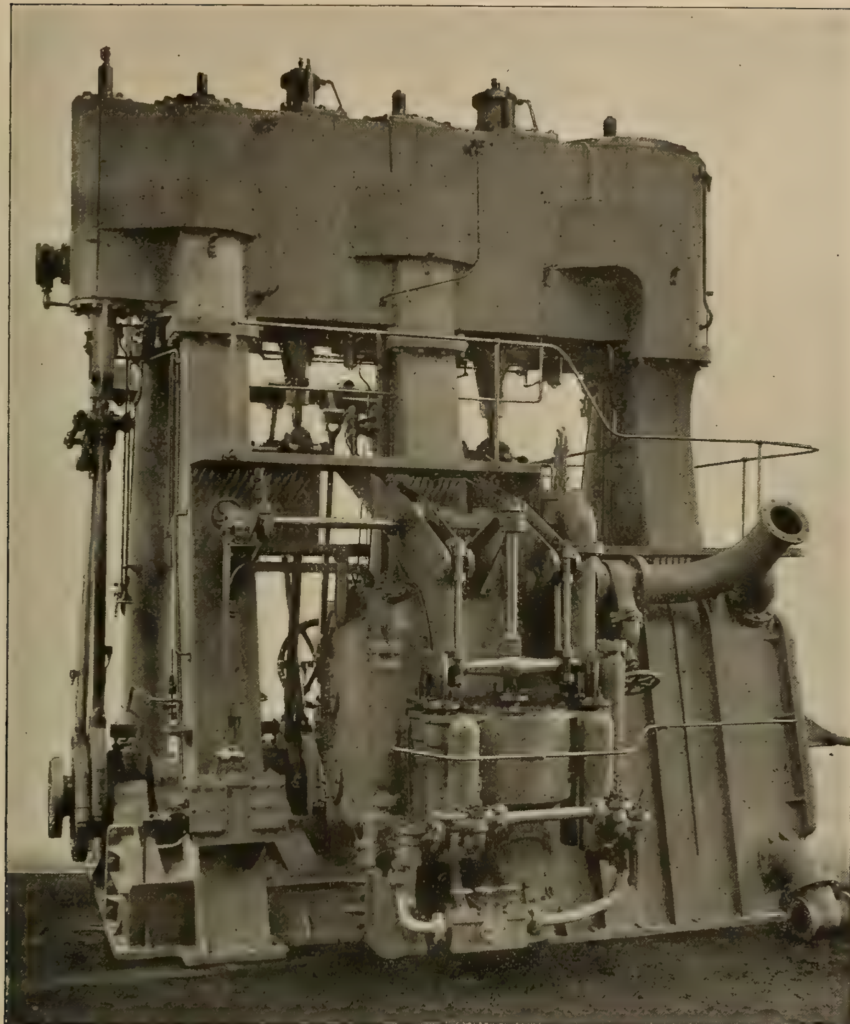


FIG. 16. FAIRFIELD CO., 1893. S. S. "CAMPANIA." TWO H. P. CYLINDERS, 87 IN. DIA. ONE INTERMEDIATE CYLINDER, 79 IN. TWO L. P. CYLINDERS, 98 IN. STROKE, 69 IN.



A SET OF TRIPLE EXPANSION MARINE ENGINES, CYLINDERS, 23½, 37 AND 61 INCHES IN DIAMETER, 42-INCH STROKE. WORKING PRESSURE, 160 LBS. 1500 I. H. P. BUILT BY SIR CHRISTOPHER FURNESS, WESTGARTH & CO. LTD., MIDDLESBORO-ON-TEES, ENGLAND.

largest cylinder of the twin-screw steamer *City of Lowell*, built in 1895, developing the same power, is 64 inches in diameter by 3 feet stroke, the total weight of the machinery being less than one-half that of the *City of Berlin*.

These conditions led to various attempts looking to a further sub-division of the power, and consequent reduction in size of parts. Some of the earliest results of these are found on the steamships *Montana* and *Dakota*, built in 1872 for the Guion line. The engines of these ships had one vertical high-pressure cylinder, 60 inches in diameter by 3½ feet stroke, working on the forward crank and driving two sets of pumps, one on each side, each connected to a condenser; and two horizontal low-pressure cylinders, 113 inches in diameter, working on an after crank of the same stroke, all the cylinders having Corliss valves.

These ships were also notable as em-

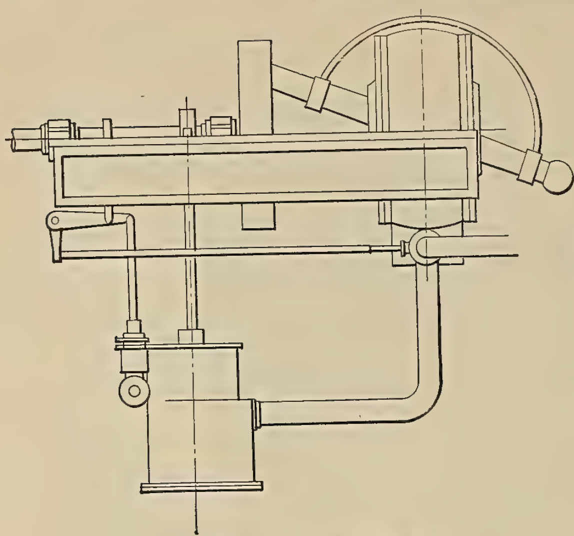


FIG. 17. RENNIE DISC ENGINE.

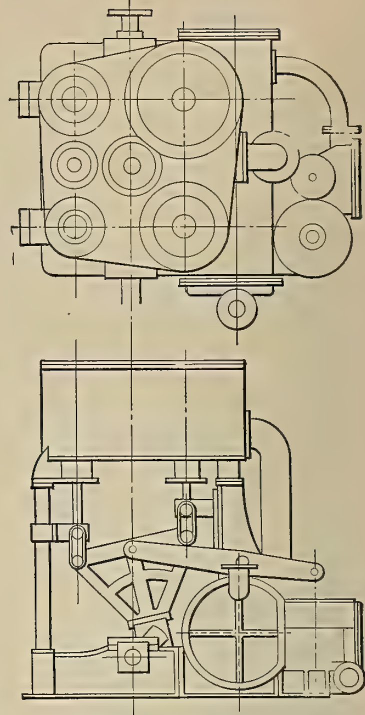


FIG. 18, FLEMING & FERGUSON, 1888. QUADRUPLE EXPANSION. CYLINDERS, 7, 9, 12½ AND 18 IN. DIA. STROKE, 12 IN.

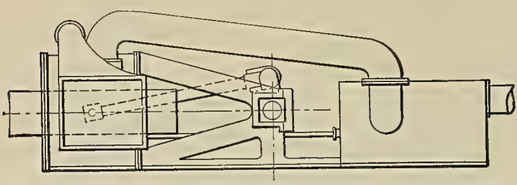


FIG. 19. PENN. TWO CYLINDERS, 55 IN. DIA. 3 FT. STROKE. 360 H. P.

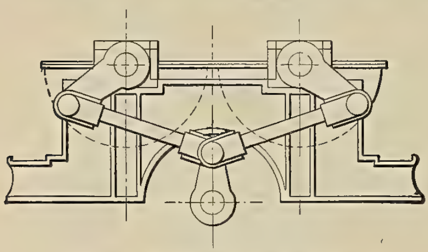


FIG. 20. ERICSSON. PRINCETON.

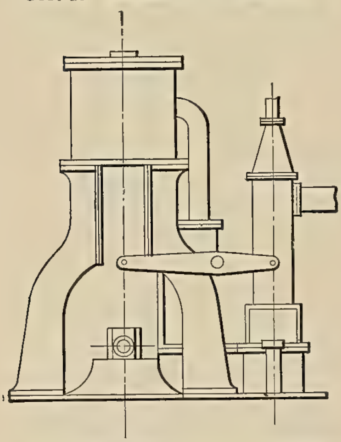


FIG. 21. THOMSON. TWO CYLINDERS, 40 IN. DIA. 34 IN. STROKE. 100 H. P.

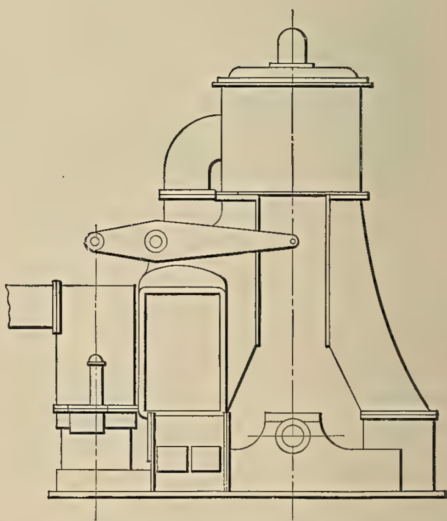


FIG. 22. NAPIER, 1866. S. S. "PEREIRE." TWO CYLINDERS, 84 IN. DIA. 4 FT. STROKE. 2500 H.P.

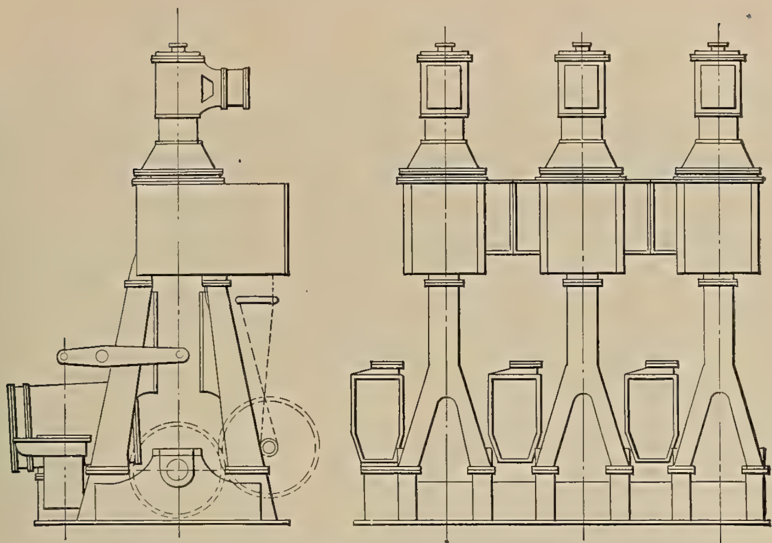


FIG. 23. ELDER, 1878. S. S. "ARIZONA." ONE HIGH PRESSURE CYLINDLR, 62 IN. DIA. TWO LOW-PRESSURE CYLINDERS, 90 IN. DIA. 5 FT. 6 IN. STROKE.

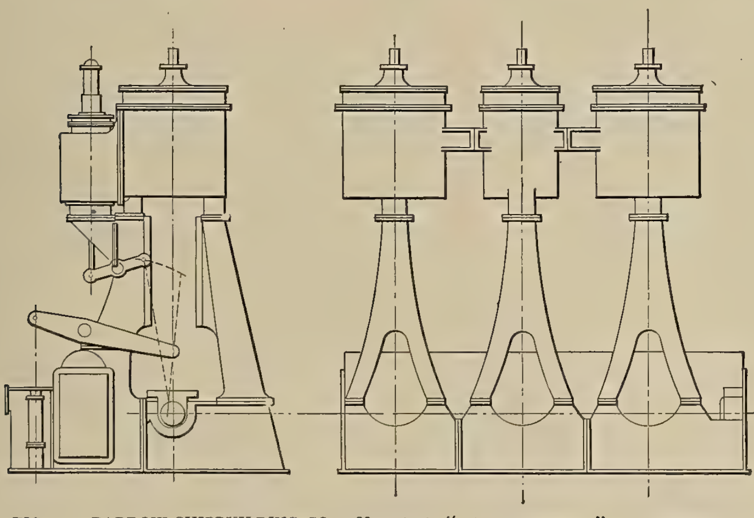
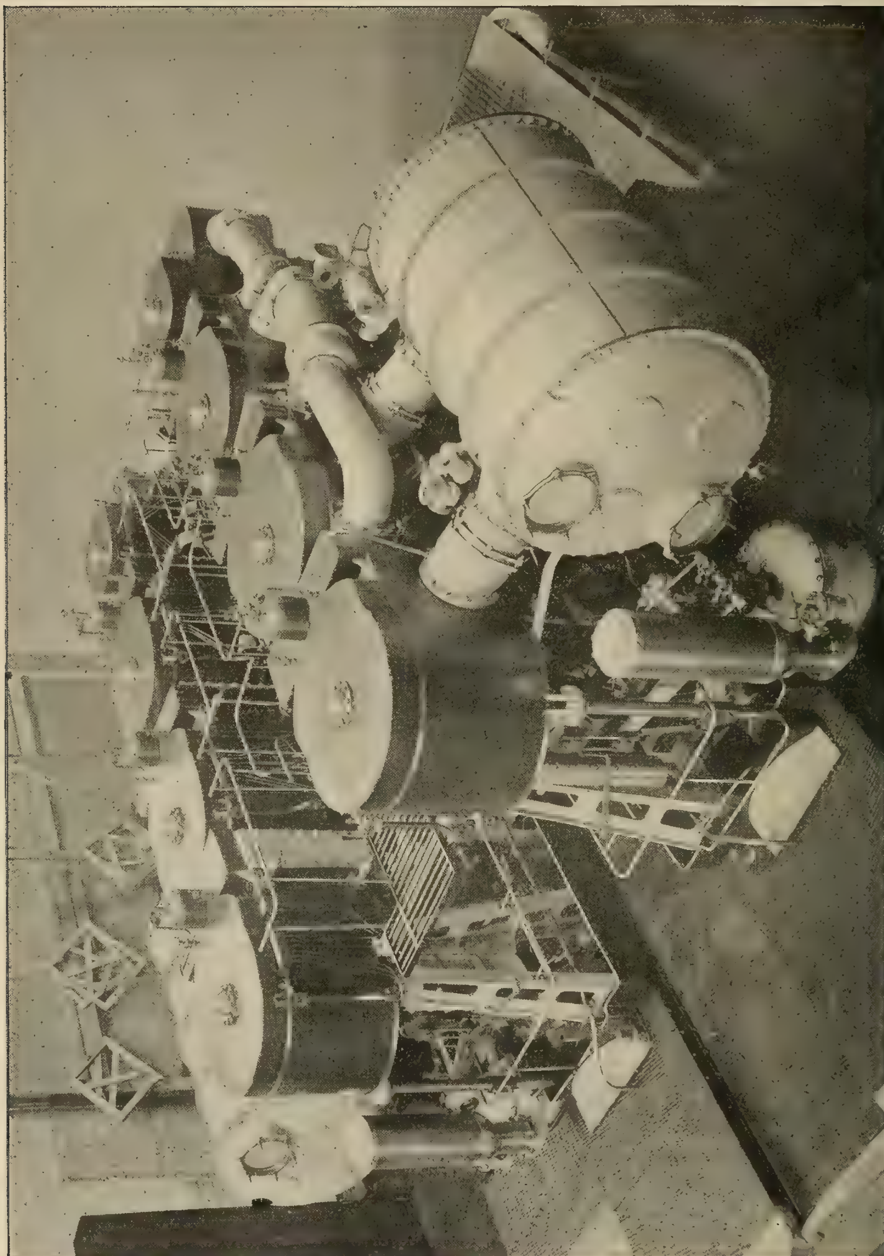


FIG. 24. BARROW SHIPBUILDING CO., 1881. S. S. "CITY OF ROME." CYLINDERS, 46 AND 86 IN. DIA. STROKE, 6 FEET.

bodying the first attempt under anything like modern conditions, in the use of boilers of the water tube type for marine purposes. These boilers were built for 100 pounds working pressure, but were unsuccessful, owing to defective circulation and lack of proper provision for expansion. They were removed before making a voyage.

After these ships came several vessels fitted with three-crank, vertical, compound engines, among which may be named the *Arizona* and *Gallia* (1879) and the *Servia* and *Elbe* (1881), the usual arrangement being for the high-pressure cylinder to actuate the middle crank, its exhaust being divided between two larger and equal-sized low-pressure cylinders forward and aft, the cranks being placed 120 degrees apart.



ENGINES FOR THE TWIN-SCREW YACHT "GIRALDA" TWO CYLS., 25 IN. DIA.; TWO CYLS., 40 IN. DIA.; FOUR CYLS., 45 IN. DIA. I. H. P., 6500. BUILT BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD., GOVAN, GLASGOW.

In this style of engine the desired reduction in size of parts was well accomplished, and a somewhat steadier turning moment was obtained than with the two-crank engine. It was, however, found impossible to divide the power equally between the three cylinders, the high-pressure cylinder largely preponderating, and greater steam economy than obtained in the two cylinder engine was not looked for. This style of engine was introduced into steam yacht service in the United States, to which service it seemed, at that time, peculiarly adapted, by the late Samuel Stanton, who fitted them in the yachts *Vedette* (1878), *Polynia* (1880), and *Radha* (1881), with marked success.

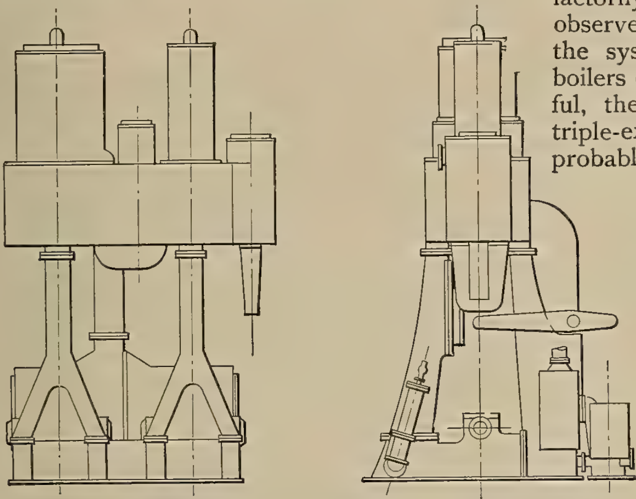


FIG. 25. MESSRS. DENNY & CO., 1888. S. S. "BUENOS AYRES." CYLINDERS, 32, 46½, 64½ AND 92 IN. DIA. 5 FT. STROKE.

In the year 1874 the steamship *Propontis*, built ten years previous, was fitted by Messrs. John Elder & Co., of Glasgow, with an engine in which steam was worked successively in three cylinders before being passed to the condenser. The proportions of these cylinders and distribution of steam were so adjusted that all the cylinders should develop equal power. This engine was designed by the late Alexander C. Kirk, and its general plan is shown by the illustrations on the two pages following.

Steam for this engine was furnished by water-tube boilers of Rowan & Horton s patent, which were afterwards replaced by shell boilers of the usual Scotch type, with which the engine did good service for manyyears, soon satisfactorily demonstrating to careful observers the entire success of the system. Had the original boilers of this ship been successful, the general adoption of the triple-expansion engine would probably have been forwarded nearly ten years. The prevalenttype of boiler, however, was distrusted for pressures much above 100 pounds, and somewhat of the ill success of the water-tube boilers was, doubtless, associated in the public mind with the triple-expansion system, of which, in fact, it was but an unessential part.

It was not until about 1882 that general attention was directed to this type of engine by the notable success of the steamship *Aberdeen*, which was fitted with a three-crank triple-expansion en-

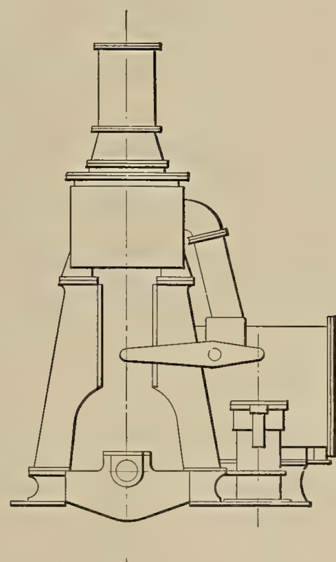
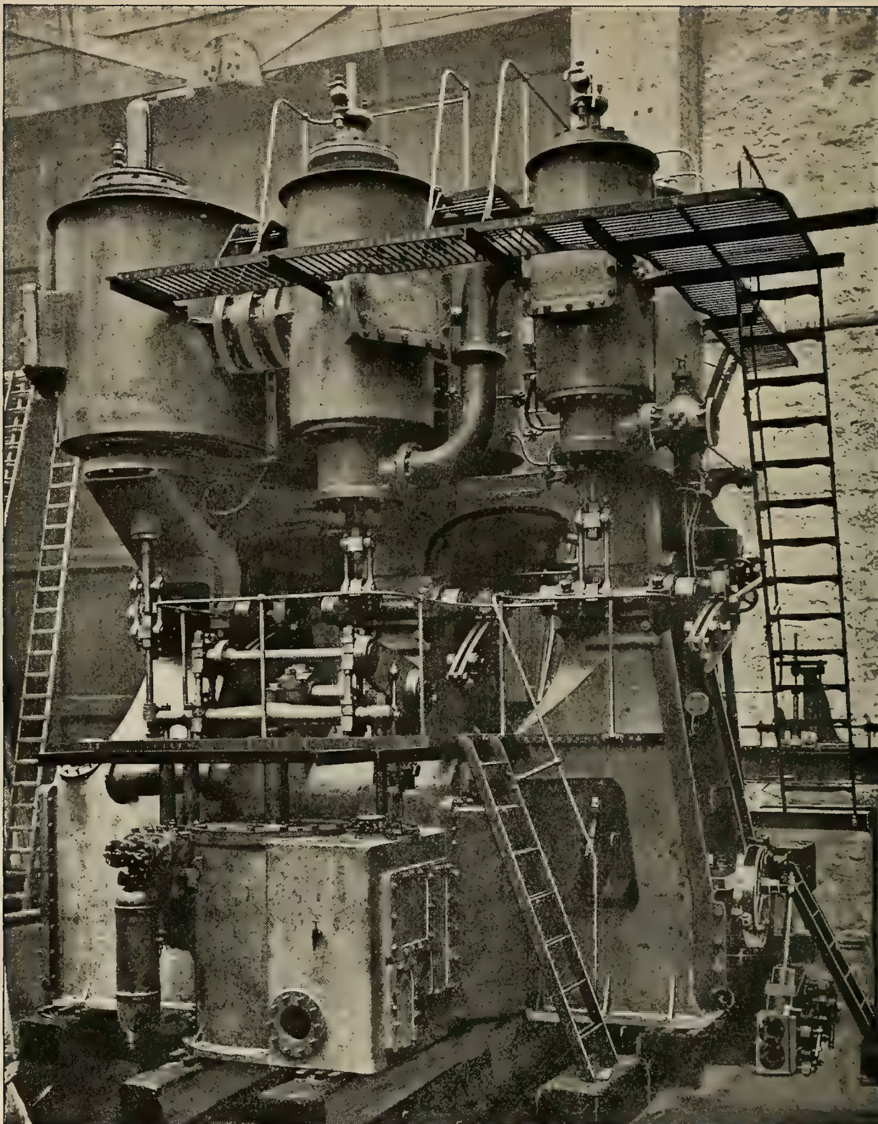


FIG. 26. MAUDSLAY, 1874. S. S. "ADRIATIC." TWO H. P. CYL., 48 IN. DIA. TWO L. P., 83 IN. DIA. 5 FT. STROKE.



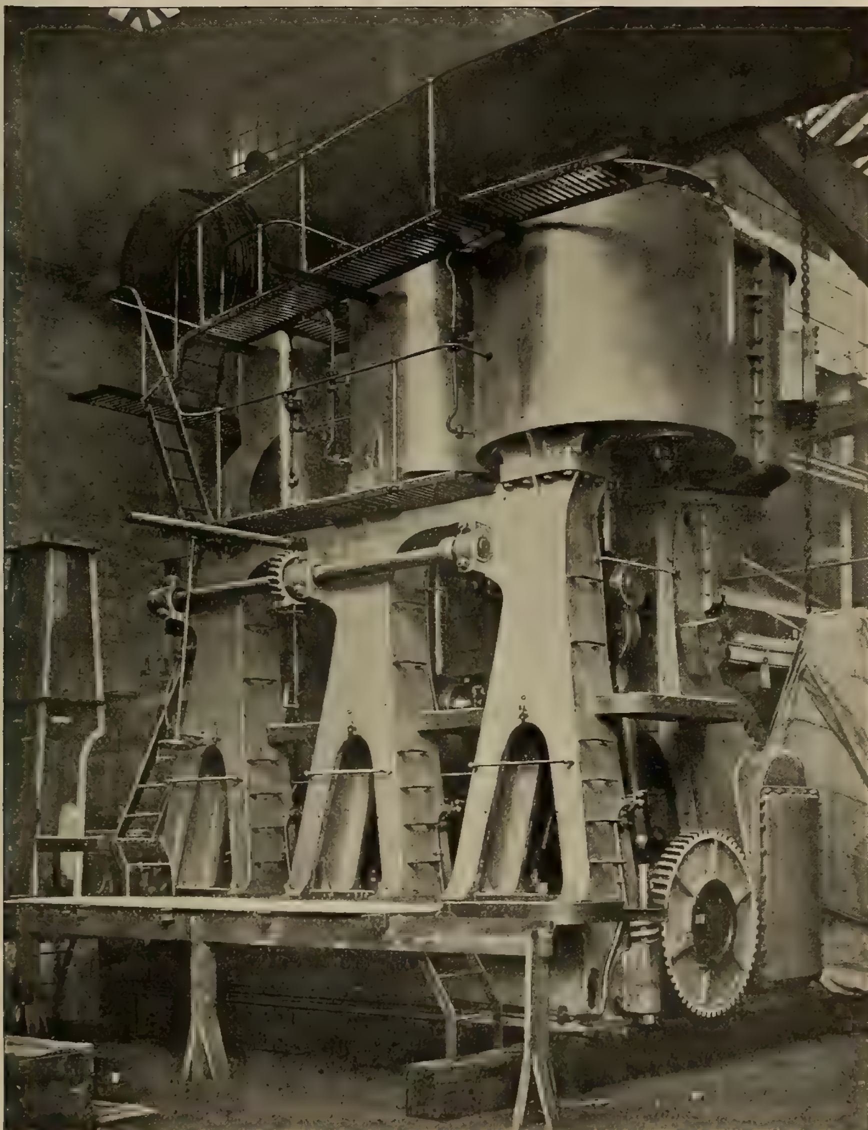
THE ENGINE OF THE STEAMER "PROPONTIS," 1874.

gine of Kirk's design, having cylinders 30, 45 and 70 inches in diameter by 4 feet 6 inches stroke, and which developed an indicated horse-power on a consumption of less than one and one-half pounds of coal per hour, and in other respects performed admirably from the start. This ship had two double-ended steel boilers of the ordinary Scotch type with six corrugated furnaces each, and carrying a working pressure of 125 pounds.

The total grate area was 210 square feet, and heating surface 7128 square feet. The ship was 350 feet long, 44 feet beam and 33 feet deep. She made 13¾ knots with 2000 tons of cargo on board, the engines indicating 2631 horse-power. The cylinders of this engine were partially steam jacketed, had piston

valves (excepting the low-pressure cylinder), and in arrangement and all essential details the engine was, practically, the triple-expansion engine as we see it to-day. The *Aberdeen*, though built for the Australian trade, made one voyage to the United States after she had been running about seven years and at that time showed herself in most excellent condition, both in engines and boilers, for active and continued service.

From this time on (1882) the practical success and general adoption of the triple-expansion engine was assured. During the year 1885, of 122 steamers over 1000 tons, built in Great Britain, 48 were fitted with triple-expansion



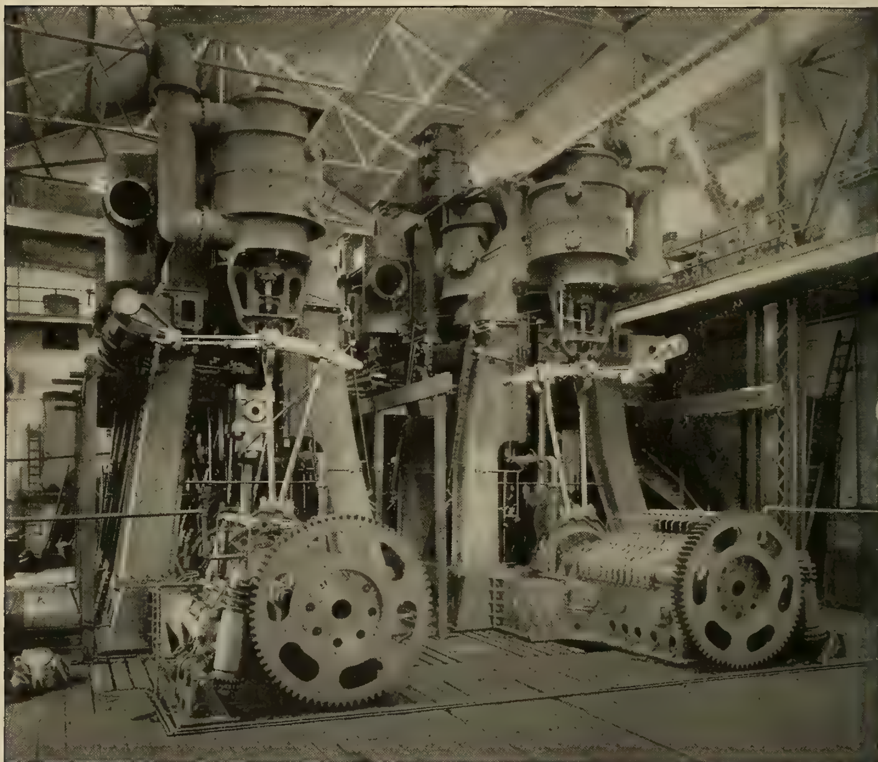
ANOTHER VIEW OF THE "PROPONTIS" ENGINE.

machinery, and 74 with compound. In 1892 the whole number built over 1000 tons was 211, of which 210 had triple-expansion machinery; and at the present time the construction of single and compound engines, except for small boats, say 200 tons and under, has practically ceased.

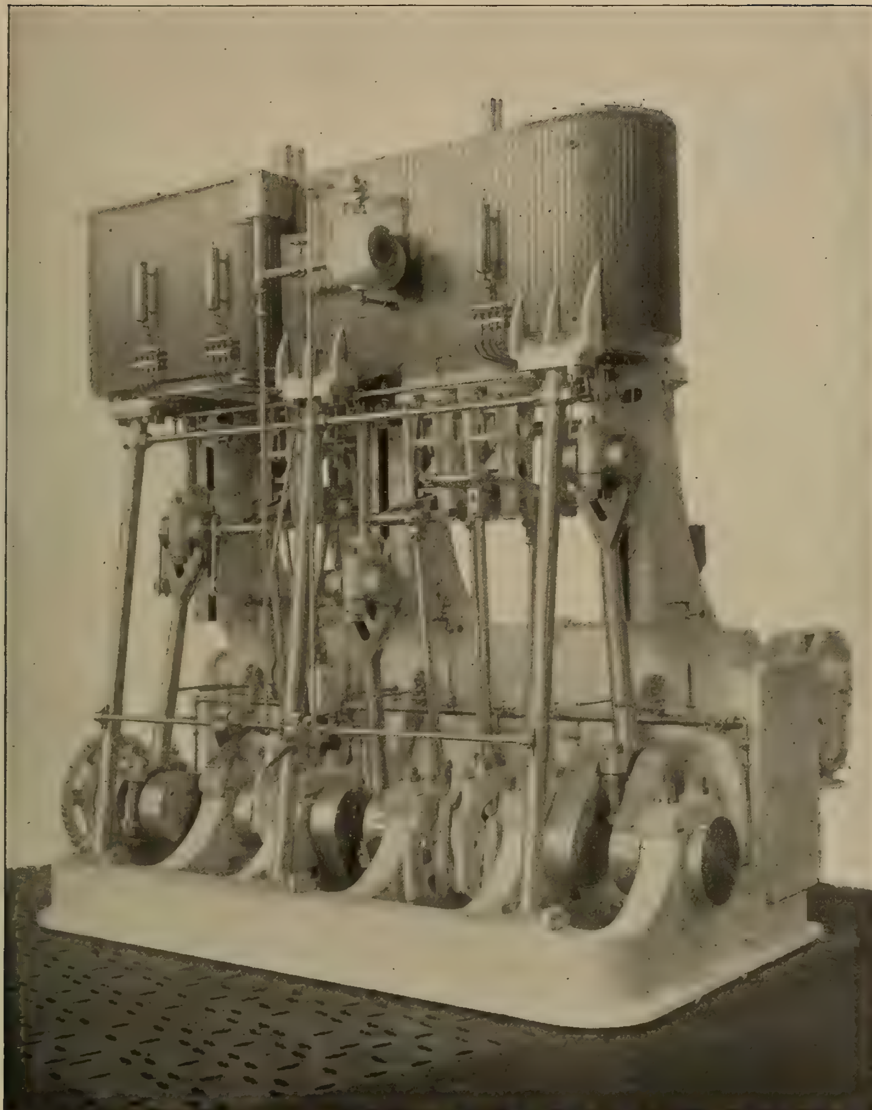
The first ship having triple-expansion engines to enter the transatlantic trade was the *Martello*, built in 1884 for the Wilson line by Earle's Ship Building Company, of Hull. This ship was 370 feet long, of 43 feet beam and 28 feet deep. She had engines with cylinders 35, 50 and 82 inches in diameter and 57 inches stroke, carried 150 pounds working pressure, indicated 2400 horse-power and made 12 knots on a consumption of thirty-eight tons of coal per day.

In 1886 the North German Lloyd Co. placed in service the fine steamers *Aller*, *Trave* and *Saale*, built by the Fairfield Company, with engine cylinders 44, 70 and 108 inches in diameter and 72 inches stroke, thus being the first of the large passenger lines to adopt engines of the triple-expansion type.

The triple-expansion engine being fairly established in popular favour, the commercial balance soon adjusted itself to the new conditions of greater economy of operation, and engine builders began to seek avenues for still further advancement, which naturally took the direction of quadruple expansion. It was soon found, however, that further advance by means of expansion in consecutive cylinders offered much less promise than in the past, and that improvement was rather to be looked for



20,000 H. P. ENGINES OF THE STEAMER "ST. LOUIS." BUILT FOR THE AMERICAN LINE BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHIA. QUADRUPLE EXPANSION. TWO 28½ IN., ONE 55 IN. AND TWO 77 IN. CYLINDERS. STROKE, 60 IN. WORKING PRESSURE, 200 LBS.



TRIPLE EXPANSION YACHT ENGINE. BUILT BY THE BATH IRON WORKS, BATH, ME., FROM DESIGNS BY CHARLES E. HYDE. CYLINDERS, 18, 28 AND 45 IN. IN DIA., AND 30 IN. STROKE.

in the use of various small economies, hitherto neglected as profitless or impracticable refinements.

Among these may be named the distilling apparatus now in almost universal use by which the unavoidable waste of water from numerous small leakages is made up by fresh water, condensed from the sea in a separate vessel which receives the deposit of salt that would otherwise accumulate upon the evaporating surfaces of the boilers and greatly reduce their efficiency; feed water heaters,—heating the water entering the boilers nearly to the boiling point, either by live steam or by exhaust from one of the cylinders; some form of hot air draught, transmitting part of the

heat of the escaping gases to the air entering the furnaces; the substitution of a high grade of bronze for cast iron in the manufacture of the propeller, allowing thinner, sharper-edged and smoother blades and greatly increasing the efficiency of the propelling instrument; the more complete covering of boilers, cylinders, and steam pipes with non-conducting material; and the more careful designing, with a view to greater steam economy, of pumping and other auxiliary machinery.

Several establishments have now, however, been engaged for some years in the manufacture of quadruple-expansion engines and a considerable number of these engines may be found in use at the present time. The most common form of this engine is that in which two cranks are used, placed at 90 degrees, each actuated by two cylinders placed steeple fashion over it.

The fine twin-screw steamers *St. Louis* and *St. Paul* of the American line, the first to use quadruple expansion in the transatlantic trade, have engines fitted with six cylinders of the following diameters:—Two high-pressure, 28½ inches; one first intermediate, 55 inches; one second intermediate, 77 inches; and two low-pressure, 77 inches. The high pressure cylinders are placed steeple fashion over the low pressure, and the first over the second intermediate, working on four cranks. The stroke is 5 feet. Steam at 200 pounds pressure is supplied by six double end and four single end boilers of the Scotch type. The total grate surface is 1144 square feet, and heating surface 40,320 square feet. Hot air draught on the Howden system is used.

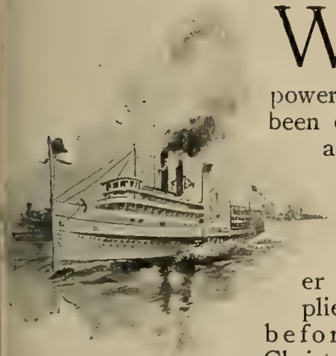
The shell plates of these boilers are 1 9-16 inches thick, the longitudinal seams being riveted with four rows of 1½-inch rivets each side of the seam. The daily coal consumption of these ships is said to be 310 tons, which is about 7 per cent. less than would be used by triple-expansion machinery under similar conditions.

The future of the quadruple-expansion engine would seem to be largely dependent upon the perfecting of the water-tube boiler, as with the advent of a boiler of that type which will exhibit such a degree of economy, durability and facility of repair as to secure its general adoption, one of the chief causes now tending against the use of the quadruple expansion system, namely, the difficulty of obtaining boilers which can be economically built and successfully kept in continuous service under the required high pressure and temperature, will disappear.

The half-tone illustrations given in this article, though representative of different types of marine engines, are naturally but a small number of those entitled to appearance here. Some of these will be found in other articles in this number, and may well be referred to for interesting comparison.

AMERICAN SOUND AND RIVER STEAMBOATS.

By L. N. Lovell, Assoc. M. Am. Soc. N. A. & M. E.



WHILE the application of steam for power purposes has been developed more and more as the years have come and gone, yet the fact that power could be so applied was known before the time of Christ. "It was recorded," so says Brown, in his history of "The First Locomotive in America," "130 years before the Christian era, that the elder Hero of Alexandria is the first author who gives an account of the application of vapour of boiling water as a power. Hero expressly ascribes the sounds produced by the Statue of Memnon to steam generated in the pedestal and issuing from its mouth. Champollion, who is the highest authority on this point, declares that the Memnon of the Greeks is identical with Prince Amenophies, the Second, one of the Egyptians who reigned at Thebes 1600 years before Christ."

Perhaps this is far enough back in the dim twilight of history to begin the sketch of the use of steam for navigation. At any rate, it is as ancient as anything at hand, and will serve our purpose. The interesting author, from whose work we have quoted, says further:—

"Blanco de Garey, an officer in the service of the Emperor Charles, the Fifth, made at Barcelona, Spain, in the year 1543, an experiment in a vessel

ON THE DECK OF AN ALBANY DAY BOAT ON THE HUDSON RIVER.

THE STEAMER "NEW YORK" OF THE HUDSON RIVER LINE.

which he forced through the water by an apparatus, of which a large kettle with boiling water formed a conspicuous part.

"De Garey was, therefore, not only the first inventor of a steamboat, but the first who was successful in applying steam to useful purposes. His machinery was imperfect and the recollection of his experiment would have been lost, had not the record been accidentally found among the ancient archives of the province of Catalonia."

Numerous efforts were made to accomplish the purpose of propelling vessels by steam from the time of Garey, some of which were partially successful,—for instance, those of Rumsey and Fitch, both of whom constructed boats propelled by steam as early as 1783. Captain Samuel Morrey, of Orford, N. H., sailed up and down the Connecticut river on a boat thus propelled, and Elijah Ormsby navigated the waters of Providence river in a steamboat in 1792.

Further experiments were made by John Stevens, Chancellor Livingston and others, but yet the credit of inaugurating this system of navigation belongs to Fulton, as from the time of the building of the *Clermont*, in 1807, down to the present, the development has continued with unbroken progress. The story of the *Clermont* has been told so often as to be familiar to all. The engine for this boat was constructed by Boulton & Watt in England, and was brought to the United States to be placed in the hull built for it.

Navigation on that famous American river,—the Hudson,—has developed two classes of steamboats,—one for night service, carrying a large amount of freight, and a large number of people who must have places in which to sleep, as well as accommodations otherwise. This demand for night service was well complied with in the steamboats of a generation ago, such as the *Isaac Newton*, and the *Hendrick Hudson*. It has been more recently provided for in the new steamboat *Adirondack* of the Albany Night Line.

The other class is for day-time travel, and this has never been more fully accommodated than in the splendid steamboats of the Albany Day Line, and the *Mary Powell*, whose speed and equipment are all that any traveller could desire. The peaceful character of this Hudson river navigation is in striking contrast to the old-time competition which prevailed in every direction.

The grand body of water, known as Long Island Sound, which connects the manufacturing part of New England with New York, could not remain "unfretted" while the steam navigation of the Hudson river went on, and we find, in 1817, that the steamboat *Firefly* was sent from New York to run between Newport and Providence, R. I. She was twenty-eight hours in making the passage, and, "though the sea was very rough as she came around Point Judith, she rode the waves in safety and was pronounced a beautiful boat."

The Providence *Journal* of 1877 gives a long and interesting account of the steamers on Long Island Sound and adjacent waters, and the writer speaks of the Providence sloop packets that carried passengers and freight between that city and the different ports on Long Island Sound and to New York. They were models of marine structure, and some of them are still afloat, matching in speed many a yacht of more recent construction. The captains of these packets were men who maintained the dignity of their position,—more conscious of their superiority to ordinary mankind than are their successors, the masters of the steamboats, in their uniforms.

On July 12, 1822, the Rhode Island and New York Steamboat Company was organised, and the steamers *Connecticut* and *Fulton* began making regular trips between Providence and New York, touching at Newport each way. The Providence *Journal*, in connection with this, says:—

THE FORWARD MAIN SALOON OF THE HUDSON RIVER STEAMER "NEW YORK."

"The circumstances which brought the *Connecticut* to Providence are of interest. The legislature of New York had granted great privileges to the Livingston and Fulton Steam Navigation Company. No steam vessel could navigate New York bay, Hudson river, Long Island Sound, or any of the lakes and rivers of the State of New York,

THE FORWARD STAIRWAY ON THE HUDSON RIVER LINE STEAMER "NEW YORK."

without their license. Thereupon the Connecticut legislature enacted that no vessel bearing such a license should enter any waters within that State. The *Connecticut* at this time was running between New York and New Haven. She was in opposition to the packet line, and it was through the influence of packet owners that the legislature of Connecticut passed its prohibitory law. The *Fulton*, running between New York and New London, and the *Connecticut*, were thus driven from the Connecticut ports. These boats were owned in New York. The *Connecticut* was about 150 feet long, 26 feet wide, and of about 200 tons burden."

The history of steamboating on Long Island Sound, from the time of its beginning as here indicated, through the years from 1822 to 1847, is extremely interesting. The violent opposition between different lines, and the active competition for the increasing traffic, resulting from the opening of the Boston and Providence railroad in 1837, kept matters in violent agitation. The racing of steamers on Long Island Sound was equal to that on the North or Hudson river, except that there was a less number to take part in it, while the dangers from the sea were much greater, some steamers being lost from collision and fire.

In 1847, the steamboat *Bay State* was built for the Fall River Line, and, in some respects this boat may be said to mark a new era in Sound navigation. In this craft were carried out ideas which had not prevailed up to that time. The fact was made evident that steamers of a somewhat different class were required for Sound navigation than for the Hudson river, and this boat was

built with great strength, and power given her to drive the increased weight at a higher rate of speed.

When the hull was being built, there were serious discussions as to the weight of timber that was being put into her, and she was called a "lumber yard." But the many years of successful operation settled the question of strength, and the very first trip she made from New York to Fall River as well determined the question of speed as compared with other steamboats of that time. And yet, compared with the steamboats of to-day, she would look poor indeed. In that day, however, the *Bay State* attracted universal attention. She had forty-eight state rooms, but no one except a reckless spendthrift,—some young fellow who had more money than brains,—would think of paying $1 for a night's rest in a room when he could have a berth without extra charge.

There were no such things as continuous tickets. Those that existed were bought in New York or Boston and simply took the bearer from one place to the other. The heating was done by stoves in the saloons, and the rooms in winter were too cold to permit of having water for ablution until morning. Boots to be blacked were put outside the room doors on retiring, and returned in the morning; if there were too many to be blacked during the night, slippers were left to be worn until the boots were returned.

The lighting was done with oil lamps, hung on a pivot in each room or in the hall, while in the dining room in the forward cabin the tables were as brilliantly lighted as wax candles could do it. The supper was table d'hote, fifty cents for each passenger, and the luxury of this feature was renowned not only at home but abroad. The long tables were loaded with all that the season could afford. The passengers were not permitted to reach them, until the captain, with whatever guests he might have, had taken his seat. Great efforts were made to obtain for these tables the first in the market of whatever might be procured, and the fact was duly and amply announced in the newspapers. The dimensions of the *Bay State* were,—length on water line, 300 feet; and breadth of beam, 59 feet. She had a vertical beam engine, with a cylinder 76 inches in diameter by 12 feet stroke. A trip on the Hudson river with its

THE HUDSON RIVER STEAMER "ALBANY" UNDER THE POUGHKEEPSIE BRIDGE.

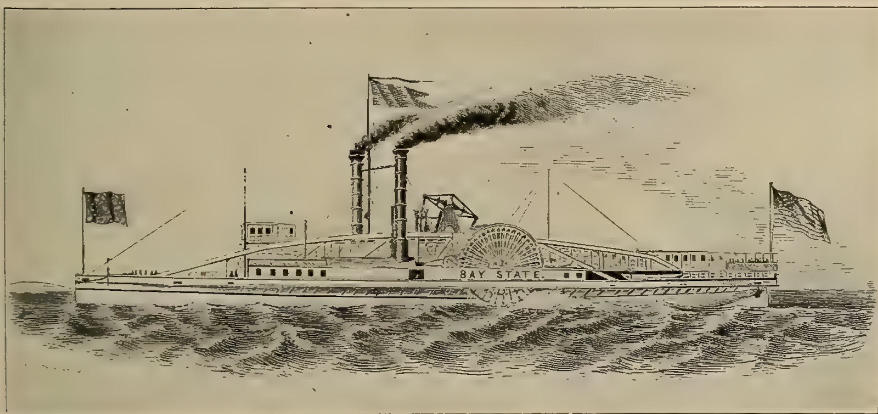
THE FALL RIVER LINE STEAMER "PROVIDENCE," 1866. LENGTH OVER ALL, 375 FEET. WIDTH OVER GUARDS, 83 FEET. DEPTH OF HOLD, 16 FEET

shores dotted with villages and its localities made memorable by Washington Irving and others, has been, and always will be, attractive to travellers. The waters of New York harbour and the beauties of Mount Hope and Narraganset bays, with the added traverse of Long Island Sound and the ocean, have also been frequently portrayed by writers of note.

Those who are familiar with Cooper's works will remember that chapter in his novel "The Water Witch," which describes the chase of the *Skimmer of the Sea* by the *Coquette* through the passages of water skirting the city of New York, by Blackwell's Island to Hell Gate, and thence into Long Island Sound. He says:—

"Hell Gate is memorable for causing many a gentle bosom to palpitate with a terror that is a little exaggerated by the boding name, though it is constantly the cause of pecuniary losses and has, in many instances, been the source of much personal danger. There is a quick tide throughout the whole distance between the harbour and Throgmorton, while it is permitted to poetic license to say that, at the narrowest part of the channel, the water darts by the land like an arrow from its bow. Owing to a sudden bend in the course of the stream, which makes two right angles within a short distance, the dangerous position of many rocks that are visible, and more that are not, and the confusion produced by currents, counter-currents and eddies, this critical pass has received the name of Hell Gate."

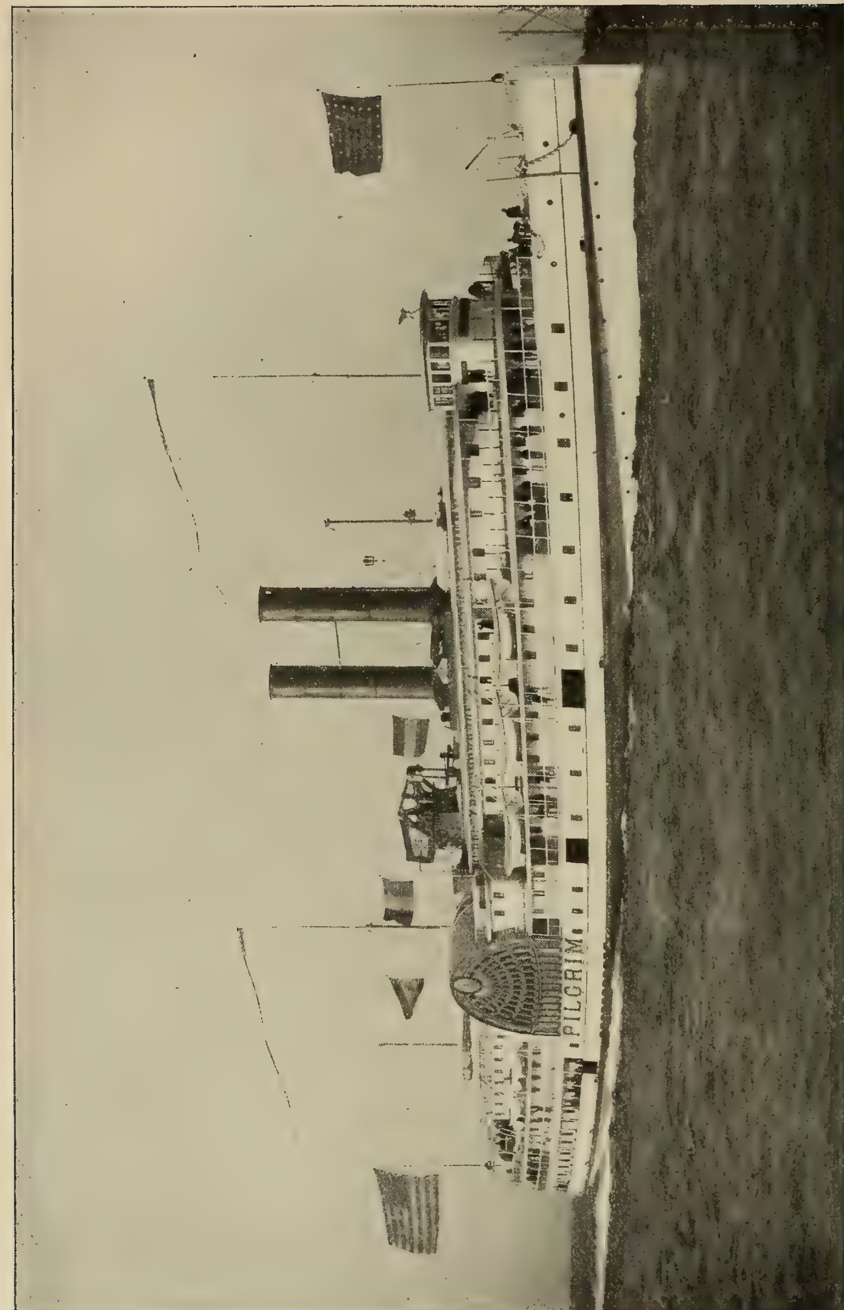
The name still remains, but, owing to the removal of many of the rocks the passage has been changed, and, except for the sharp turns still necessary, is as safe as any other part of the course from the harbour of New York to Long Island Sound proper.



THE STEAMER "BAY STATE," 1847.

From the time of the *Bay State*, and even before that period, Long Island Sound has been a great highway of travel. It is the connecting link not only between the cities of New York and Boston, but between large sections of the country. A host of people move in the winter time from the cold climate of New England to the warmer Southern and Western atmospheres, and in summer the shores and mountains of New England are sought by the Southern and Western dwellers. Not only is the passenger travel very heavy, but the freight movement of raw material and manufactured goods is very great.

Railroad competition with steamboats has, in most instances, been altogether to the advantage of the former, and the wonderful development in track and equipment has added to this advantage; yet the natural competition between the railroads and steamboat lines on Long



THE FALL RIVER LINE STEAMER "PILGRIM," 1883. LENGTH OVER ALL, 390 FEET. WIDTH OVER GUARDS, 88 FEET. DEPTH OF HOLD, 15⅓ FEET. I. H. P., 5300. BUILT BY THE MORGAN IRON WORKS, NEW YORK.

Island Sound has not very greatly changed their relative positions. Each has grown stronger and better as the years have come and gone, but neither at the expense of the other.

The time occupied between New York and Boston by railroad has been very materially shortened during the last twenty years, and the comfort of the trip greatly increased. The steamboats on Long Island Sound, in their regular passage from New York to Providence or Fall River, still consume about ten hours; two or three of those hours can be employed in summer time in viewing the sights of New York harbour and the adjacent land and water, with a night's rest afterwards, and, by means of the short connecting railroad, the traveller can reach Boston in the morning in time for the business of the day.

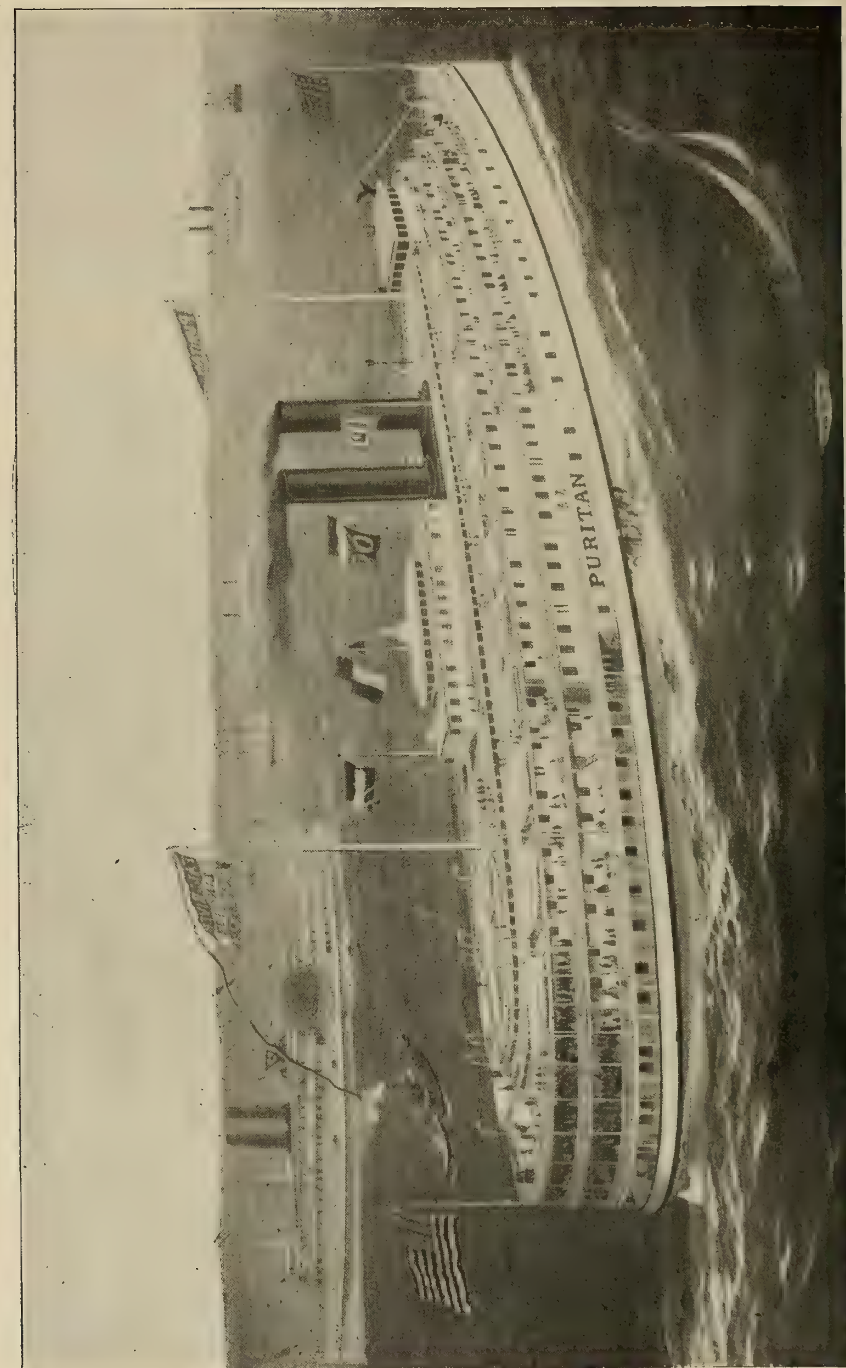
With these natural conditions in force, and the volume of business, both of passengers and freight, increasing from year to year, it would be strange, indeed, if the managers of the Sound lines had not increased the facilities to move this volume, and from time to time new steamboats were built, such as the *Metropolis*, the *Commonwealth*, and the *Plymouth Rock*, admirably designed to meet the requirements as they then appeared.

But in 1866, Mr. William H. Webb built two steamers, the *Bristol* and the *Providence*, which were far ahead of all their predecessors in many respects. They were larger, had more power, and carried one deck more than any steamboats before built, and were designed to carry many more passengers. Whatever may have been the idea of the traveller in the first days of the *Bay State*, the public now demanded staterooms, and were willing to pay for them.

The dimensions of the *Providence* were as follows:—375 feet long, 83 feet beam over all, and 16 feet depth of hold. The hull proper measured 3000 tons. The machinery was built by John Roach & Son, of Chester, Pa., and New York. The boat had a simple, beam, surface-condensing engine of 2900 horse-power, the cylinder being 110 inches in diameter, and the piston stroke 12 feet. Steam was furnished by three return tubular boilers, each boiler 12 feet, 7 inches width of front, 12 feet, 5 inches diameter of shell, and 35 feet long. There were 223 staterooms and the equipment comprised all that could be devised for safety and comfort.

The care with which the *Bristol* and the *Providence* were built, was well expressed by the person who said that they were "framed as exactly as a piece of furniture for a parlor," and, throughout their construction and equipment,

MAP OF THE FALL RIVER LINE AND IMMEDIATE RAILROAD CONNECTIONS.



THE 'PURITAN,' 1888. LENGTH OVER ALL, 410 FEET. WIDTH OVER GUARDS, 91 FEET. MOULDED DEPTH, 21 FEET 4 INCHES. I. H. P., 7500.
ENGINES BUILT BY THE W. & A. FLETCHER CO., HOBOKEN, N. J.

the same care was exercised. They were lighted with gas, and, later on, were heated by steam.

When on the ways, building, they looked so high from keel to dome deck, that some said they would be top heavy, and others said they were so long that they could not safely go through Hell Gate. Steam steering gear was not put in until they had run several seasons, and any one, who had seen the effort put forth on the steering wheel of other steamboats, might question whether or not six men at the wheel could be depended upon to carry the boat safely through Hell Gate.

Hallett's Point reef in that passage had not been exploded when these steamers started. That explosion took place on Sunday, September 24, 1876, and was heard and felt by thousands of people in the upper part of New York city. The captain of the *Providence*, which was to leave New York that night, had some concern as to how matters might be in the Gate, and wondered if some great rock might not be thrown on top of the reef, and his steamer strike it as she attempted to go through. Not only were these questions discussed, but the statement was made quite generally that the steamers could not carry enough passengers and freight to pay the cost of running them, and a fair interest on the money, as they cost more than $1,000,000 each. The company which built them was unfortunate, and the steamboats were sold at auction before they were launched. Running at first between New York, and Bristol, R. I., there connecting with the railroad for Boston, they and it formed the Bristol route. Finally these were acquired by, and became a part of the Fall River Line.

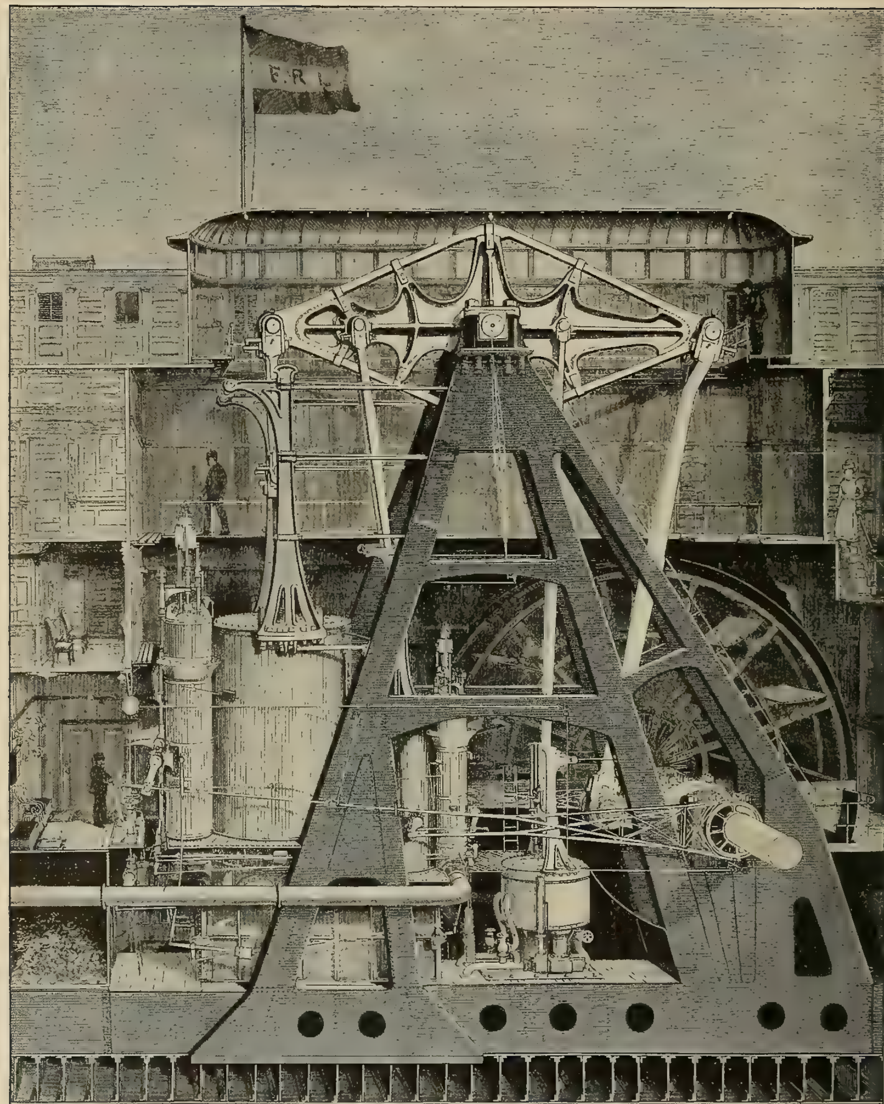
Reference has been made to the additional deck upon these steamers, which permitted a gallery tier of rooms, and for the main saloons gave height and opportunity for ornamentation not possible in the other steamboats. Perceiving this possibility in the way of decoration, the interiors of these boats were painted with a blending of colours and showed the evidence of cultivated taste, and cultivated people have from the beginning travelled on these boats.

On June 28, 1817, the *Firefly* was sent from Providence to Newport to meet President Monroe of the United States and take him to Providence, and from that time to the present, not only have the names of most of the presidents of the United States appeared upon the passenger lists of these Sound steamers, but also those of many other distinguished people. The fame of these steamers has extended to all lands whence travellers come. There is nothing very like the modern Sound steamer anywhere else in the world, and few foreigners of the better class visiting the United States, return home without seeing, or taking a trip on, these steamers.

Any one can readily see that many men must be required to man these steamers. Notwithstanding the early opposition of the packet captains and crews to the establishment of steamers, they finally perceived that steam vessels were destined to supersede sailing craft, and many of them therefore gave up their sloops and sought employment on the steamboats. Wiser were these than those baggage wagon owners, who, with their eight-horse vehicles, carried leather from Boston to the neighbouring towns and brought back the shoes. They thought they could compete with the new railroad, but, as the result has shown, they were mistaken. The baggage wagons have gone; the railroads remain.

Many are the anecdotes told of these same men, from the time of Captain Smith, of the *Firefly*, down to the present era of uniformed commanders of the steamers. Two new things were introduced on the *Bristol* and *Providence*,—uniforming the officers and crew, and carrying bands of music.

In the progress of time, and with the increasing business, the steamboats of 1870 to 1880 no longer answered the demands made upon them, and in 1881 a new, and in some respects a radical, departure in steamboat building was taken. Iron displaced wood in the construction of the hulls, bringing up new



BY COURTESY OF THE "SCIENTIFIC AMERICAN."

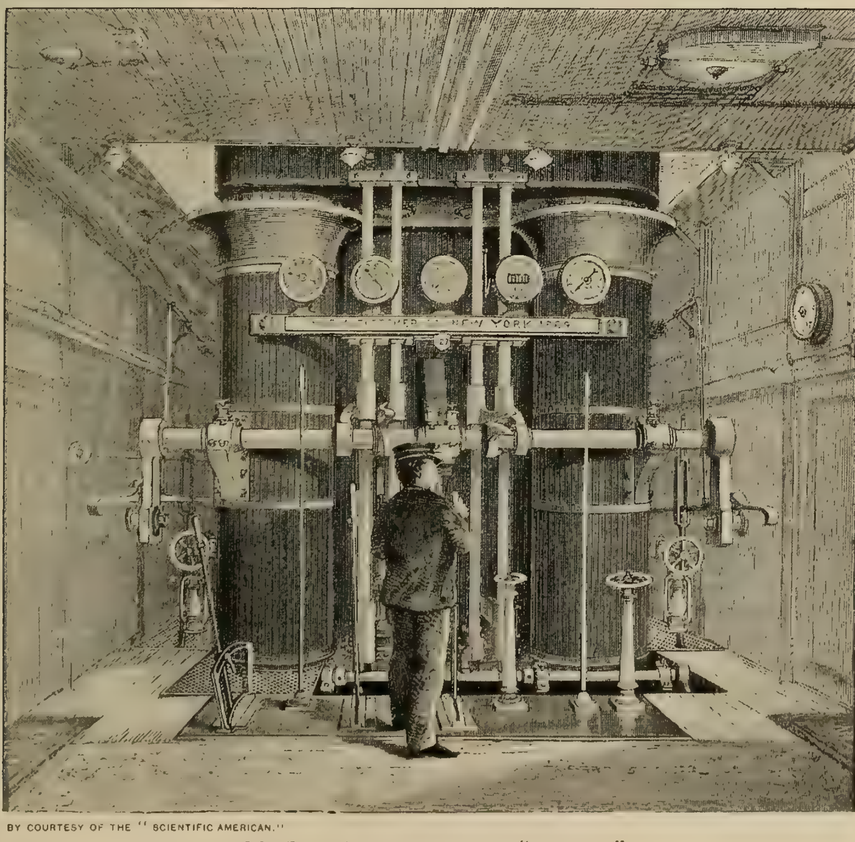
COMPOUND BEAM ENGINES OF THE FALL RIVER STEAMER "PURITAN." I. H. P., 7500.

problems to be solved, and new conditions to be met. On the ocean, propellers had long taken the place of side-wheel steamers. Taking into consideration the size of the steamers to be built; the draft of water permissible in Mount Hope and Narragansett bays; the necessity for great beam in order to give space for saloons, staterooms, boats and rafts; and the protection from collision abeam, (the dangerous point in propellers), it seemed wise to retain the wide guards, as also the midship engine and the side-wheels. To provide against the danger of sinking from taking bottom, the double-bottomed hull was decided upon, and the steamboat *Pilgrim* was built to answer all these requirements.

In ordinary work, the run from New

York to Fall River can readily be made in about ten hours, and, with everything on time, this can be allowed for it, but, with the continuous passage tickets, for instance from Chicago to Bar Harbor, and staterooms on the steamer from New York to Fall River engaged, it is a serious matter for the traveller to be late; so if the steamer can be held for a few minutes and make up the time on the passage, it is a great help. So, too, in case of detention by fog or other unforeseen cause, if the steamer can make up the time, the gain in every way is very great. To answer the requirements for speed beyond the normal, and to provide for the unusual demand that might be made, great power must be obtained.

It is the unusual that costs. The gain of an hour or two in time by an ocean steamer requires more power, and that extra power is expensive. The *Pilgrim* was built with all that time, skill and money could procure, and was given great power and everything that could be devised for the safety and comfort of the people who would travel upon her. She is 390 feet long; width, over guards, 88 feet; and depth, 18 feet 6 inches. She is built of iron, on the cellular principle, or, in other words, with two hulls, one inside the other. Between the two hulls there are ninety-six watertight compartments, and in the inner hull, beneath the iron deck, there are seven. In the interior of the vessel, every compartment in which fire is used is enclosed within iron walls, not wooden walls sheathed with iron, but solid plates of heavy boiler iron, riveted together, and absolutely preventing the escape of any fire enclosed within their protecting limits.



BY COURTESY OF THE "SCIENTIFIC AMERICAN."

IN THE ENGINE ROOM OF THE "PURITAN."

THE TWIN SCREW STEAMER "RICHARD PECK" OF THE NEW HAVEN STEAMBOAT COMPANY. BUILT BY THE HARLAN & HOLLINGSWORTH CO., WILMINGTON, DEL. LENGTH OVER ALL, 316 FEET. WIDTH OVER GUARDS, 62 FEET DEPTH OF HOLD, 18½ FEET. TRIPLE EXPANSION ENGINES. I. H. P. 4000.

In the original specifications for this steamer, it was provided that gas pipes should be put in and used for gas. Before the boat was completed, electricity was substituted, and the use of gas avoided. The steamer has rendered the most continuous service of any steamboat or steamship built, running every night in the week, including Sundays, for more than 300 consecutive days.

In July, 1888, the steamboat *Puritan* was accepted and developed in the *Puritan*, on which steamer the upper deck is made a promenade entirely around the dome deck, so that there is room to stand while looking about, and a walk of about 700 feet around the deck from starting to returning point.

The *Puritan* has a compound beam engine, with a high-pressure cylinder, 75 inches in diameter, and 9 feet stroke of piston. The low-pressure cylinder is 110 inches diameter, and has a 14

THE "PLYMOUTH," 1890. LENGTH OVER ALL, 366 FEET. WIDTH OVER GUARDS, 87 FEET. MOULDED DEPTH, 21 FEET 4 INCHES.

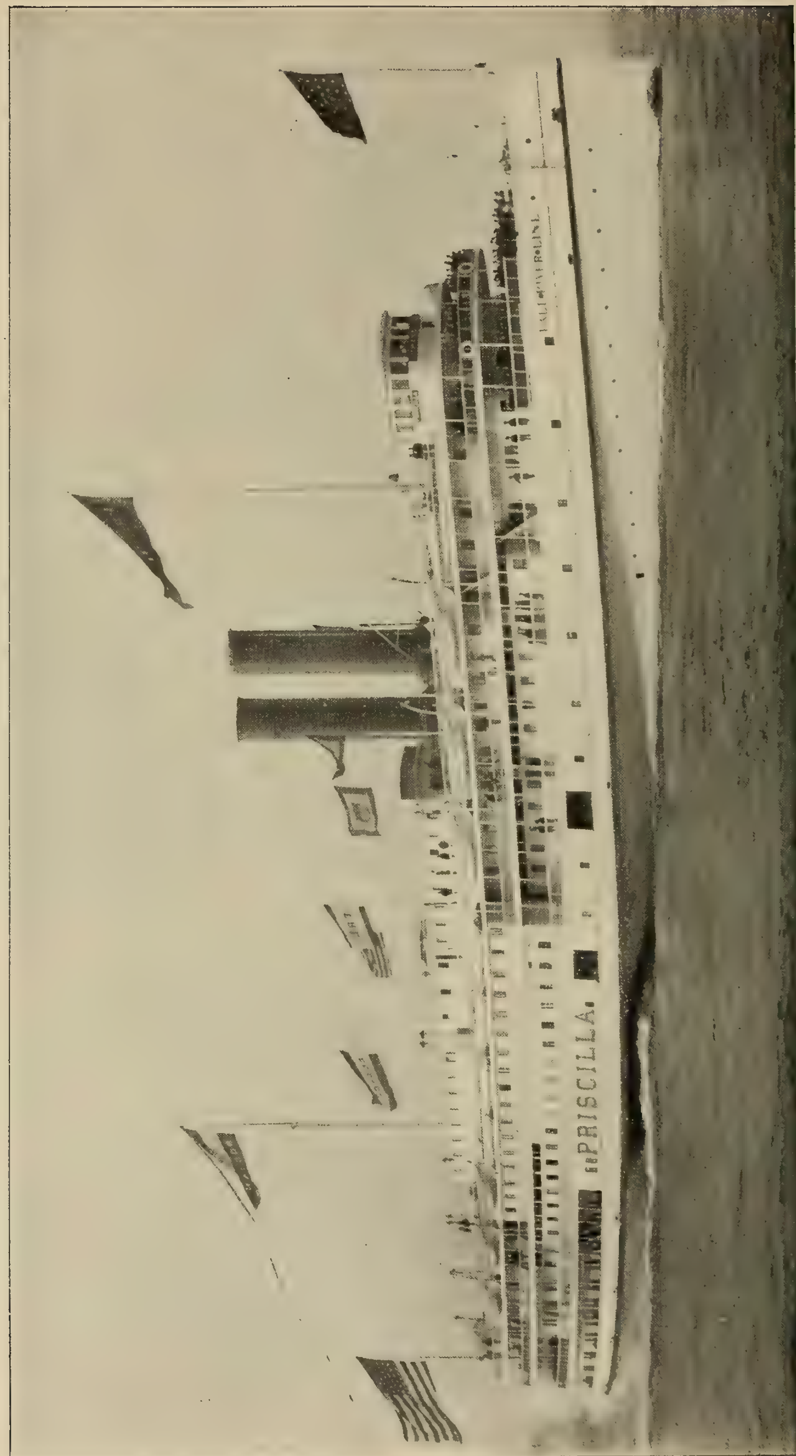
was launched, taking her place in the Fall River Line in June, 1889. She is yet larger than the *Pilgrim*, of greater power, and has a still more complete equipment.

In building these boats, many and apparently conflicting requirements appear, or needs arise which are difficult to answer. If they left New York late in the evening, passengers would come on board and go to bed; that could be provided for, but these steamboats leave New York in the afternoon and people want to be outside, looking at all that can be seen of the harbour. The then Duke of Sutherland, when on board the steamer *Bristol*, in 1881, suggested that greater provision for outdoor observation might be desirable, and the idea

foot stroke of piston. A surface condenser is placed directly under both cylinders, and is supplied with condensing water by two independent centrifugal circulating pumps. The air pump is single-acting, and is connected to the working beam at the same end as the main connecting rod, that is to say, at the end opposite that to which the cylinders are connected.

The connecting rod is made especially heavy and, with the air pump, forms a balance for the high and low-pressure pistons and their connections.

The paddle wheels are feathering, 35 feet in diameter outside of the buckets. The buckets are curved steel plates, 14 feet long and 5 feet wide. Care throughout was taken in designing the engine, so



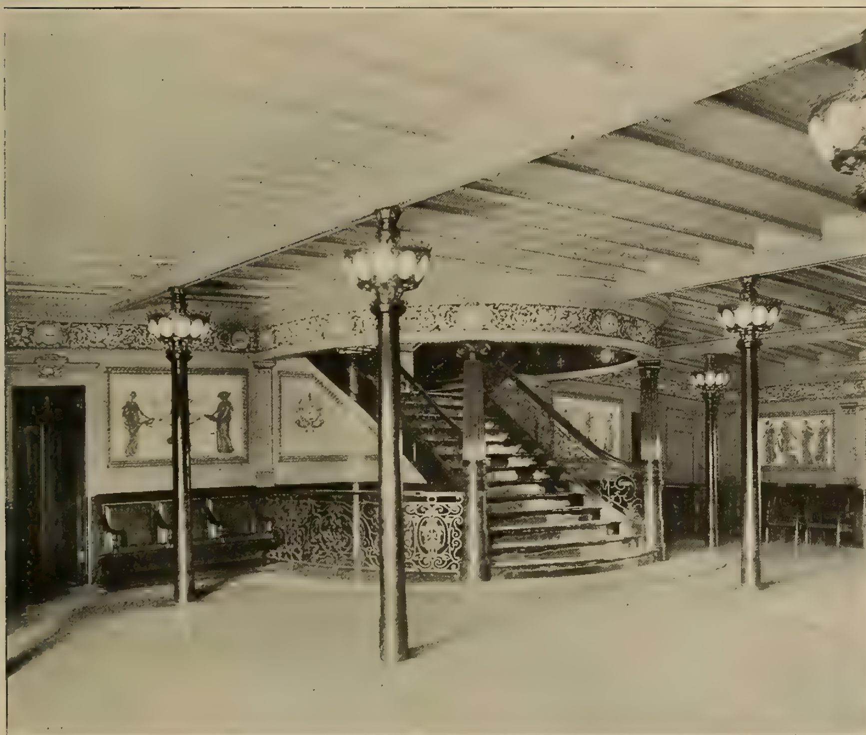
THE FALL RIVER LINE STEAMER "PRISCILLA." CONTRACTORS, THE W. & A. FLETCHER CO., HOBOKEN, N. J. LENGTH OVER ALL, 440 FEET. WIDTH OVER GUARDS, 93 FEET. DEPTH OF HOLD, 18 FEET. DOUBLE INCLINED COMPOUND ENGINE. I. H. P., 8500.

that it should be as free from derangement as possible, and the wheels were accordingly made very strong. Weighing as they do, independent of the shafts, 100 tons each, they may be looked upon as exceptional fly-wheels.

There are eight return tubular boilers of the Redfield style, having an aggregate of 850 square feet of grate, and 26,000 square feet of heating surface.

The machinery of the *Puritan* was designed to indicate 7500 horse-power, but in regular business this figure is rarely reached, six of the boilers being all that are ordinarily used. In fact, on one occasion only has the boat been run with the designed power for any length of time. On this occasion, May 26, 1893, the *Puritan*, on her way from New York to Newport, ran down the Sound with all her boilers in use. The distance from Stratford Shoal lighthouse to the whistling buoy off Point Judith, 87¼ statute miles, was made in 4 hours and 2 minutes (giving a speed of 21⅝ miles an hour), the engine making an average of 22 8-10 revolutions per minute, and developing 7700 horse-power. The tide was flood (against boat) to Little Gull lighthouse, 53 miles, and ebb (in favour) the rest of the way to Point Judith.

Probably the engine of the *Puritan* is the largest in the world; that is to say, no other engine develops as much power through one pair of cranks, and to watch these nine-ton cranks with the two shafts, each about forty tons, and the wheels (as already stated each 100 tons) making twenty-three revolutions per minute, with a regularity and smoothness unexcelled, is certainly very impressive.



THE STAIRWAY TO THE GRAND SALOON ON THE "PRISCILLA."

Following the *Puritan* came the *Plymouth*, built in 1890. She is smaller than the *Puritan*, but has the same gen-

THE DINING ROOM ON THE MAIN DECK.

eral features, except in regard to the engine, in which respect there was a radical change from the beam engine to the inclined cylinder engine.

While the development of these very large side-wheel steamers has been going on, there have been built smaller, but very complete, propeller steamers, such as the *Maine*, and *New Hampshire*, of the Stonington line, and the *City of Lowell*, of the New London line. They perform their work, carrying passengers and freight to and from their respective ports, economically and well.

The latest of the larger Sound steamers to be built, is the *Priscilla*. To show the development of steam navigation on the Hudson one may compare the *Clermont* with the *New York* or *Adirondack*. To show the extremes of Sound navigation from the beginning to the present one must take the *Firefly* of 1817 and the *Priscilla*, of the Fall River line of 1894, as examples.

Of the *Firefly*, very little informationis available. She is spoken of "as coming up the Providence river, wheezing and puffing, an ugly little thing, full of machinery and awkward in her motions. She was no match for a fast sloop with a favourable wind. She even hoisted a huge square sail to accelerate her motion when the wind was fair, but then the packets would often come into port ahead."

Even five years later than the time of the *Firefly*, when the *Fulton* and the *Connecticut* formed the first regular line from New York to Providence, the rate of speed and the amount of travel were not very great. We find the record (the time being between New York and Newport) to be as follows:—

September 13, *Fulton*, 27 hours from New York, 40 passengers.
October 4, *Connecticut*, 32 hours from New York, 40 passengers.
October 6, *Fulton*, 24 hours from New York, 26 passengers.
October 10, *Connecticut*, 18 hours from New York, 35 passengers.

In contrast then with these meagre details of the early steamboats, turn to the *Priscilla* of to-day. This boat is larger and has greater carrying capacity than the *Puritan*, being twenty feet longer. She has double inclined com-

pound engines; boilers of the Scotch, instead of the Redfield, type; and her dining room is on the main, instead of the lower, deck. It may also be added that, while a larger boat than the *Puritan* was needed for the greatly increasing business of the line, the *Priscilla* is as wide as any dry dock in New York City will admit. The dimensions and proportions of the boat are given in the following table:—

Length over all	440 feet,	6 inches.
Length on water line	423 "	6 "
Breadth over guards	95 "	
Breadth of hull	52 "	6 "
Depth of hull, moulded	20 "	6 "
Draft of water, light	12 "	6 "
Registered tonnage	5,398	

The preliminary designs for the *Priscilla* called for an engine of the same

THE "PRISCILLA'S" MAIN SALOON, LOOKING AFT.

THE MAIN SALOON, LOOKING FORWARD.

style as that of the *Puritan*, but of considerably more power. This made necessary larger cylinders, a greater surface condenser, and, above all, a much heavier working beam, and these changes brought into question the matter of stability.

There is probably no better sea boat than the *Puritan*. The general distribution of weights with her model makes her perfectly safe and easy in a seaway. The additional weight called for by the increase in power, and the placing of the same at even a greater height than on the *Puritan*, though in a larger hull, would decrease the general stability of the boat. Taking this circumstance into consideration and also the fact that to increase the dimensions of the low-pressure cylinder and the working beam of the *Puritan* engine would seem almost impracticable, caused the decision to change from the beam engine to a style in which the weights could be placed lower and the power so divided that no unusually large parts of machinery would be necessary.

The *Plymouth*, built subsequently to the *Puritan*, had, for certain reasons, been supplied with a double inclined triple-expansion engine, which gives great satisfaction, so that, on deciding to change the form of engine for the *Puritan*, it was natural to follow the

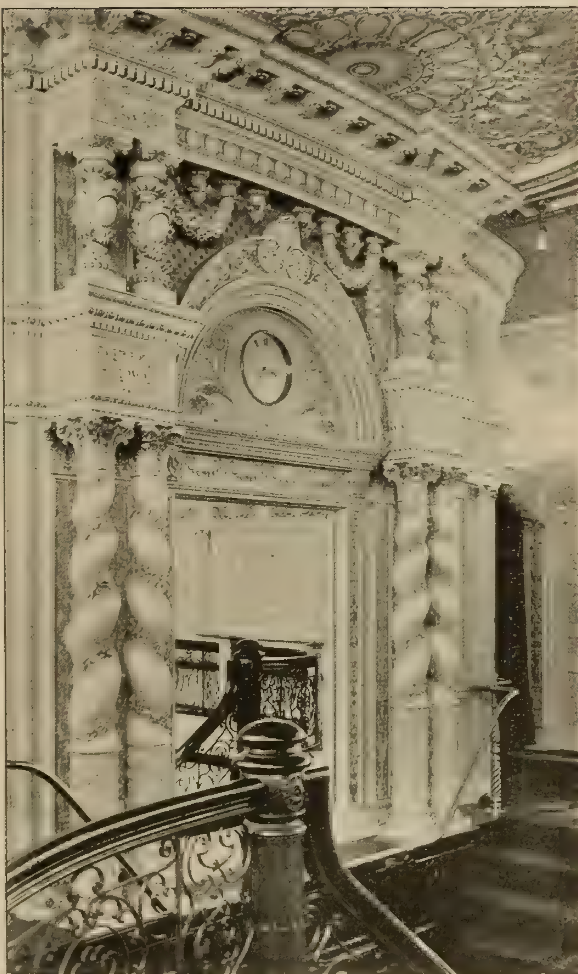
same general engine arrangement as that of the *Plymouth*.

It was finally concluded to make the new engine double inclined, of the compound type, with boilers built for comparatively high steam pressure. This gives, when in ordinary use, the economy of a high-expansion engine; but when greater speed is required, without especial regard to the finer economy, the compound arrangement affords a greater range of power.

The *Priscilla's* engine has two high-pressure cylinders, each 51 inches in diameter, and two low-pressure cylinders, each 95 inches in diameter, all having a piston stroke of 11 feet. Each of the low-pressure cylinders has its own air pump, direct attached, and its own surface condenser, with two independent centrifugal circulating pumps. There are two pairs of cranks, one high and one low-pressure cylinder being connected to each pair. The wheels are of the same style and general dimensions as those of the *Puritan*.

There are ten Scotch boilers, built for a working pressure of 150 pounds per square inch. They are each 14 feet in diameter and 14½ feet long, are provided with corrugated furnaces and Serve tubes, and have an aggregate of 850 square feet of grate surface, and about 35,000 square feet of heating surface. The boilers are arranged for forced draft when needed. Ordinarily but nine boilers are in use.

The machinery of the *Priscilla* was designed to develop 8500 horse-power, but, as in the case of the *Puritan*, only once has the boat been driven approximately with full power. On June 20, 1894, the distance from Newport to New York, 160 miles, was made in seven and one-half hours. On this run the distance between Point Judith and Stratford Shoal lighthouse, 87¼ miles, was made in 3 hours and 57 minutes, giving a speed of 22 9-100 statute miles an hour. The engine averaged 23 6-10 revolutions per minute, developing 9000 horse-power.



AT THE HEAD OF THE "PRISCILLA'S" MAIN STAIRWAY.

The idea of spaciousness that one gets upon an external view of the *Priscilla* is well supplemented by impressions received upon boarding the boat by the main gangway. The quarter deck is a

THE UPPER SALOON.

main hall by itself, generous in proportions and free and open in all its parts.

The finish and decorations of this deck give the keynote to the architectural and artistic treatment of the whole interior of the vessel. The floor is of composition, laid in the old Venetian method, with elaborate border. The covering of the walls is in mellow grays, with gilt used in great moderation.

The saloon deck overhead is supported from the quarter deck by eight stanchions. At the top of each is a cluster of ten electric lights with opalescent shields as reflectors. A dado, 3 feet 6 inches in width, rises from the deck on the walls, this and the stanchions being in mahogany finish. Above the dado are successions of panels, numbering twelve in all, each panel occupied by a group in bas relief, all original in conception and working. These groups represent, in an artistic manner, all the principal departments in the construction and purposes of the boat,—commerce, machinery, architecture, electricity, music, dancing, the arts, painting, home industry, etc. In the illustration of the last named department, reference is made to the historic Priscilla with her spinning wheel.

The dining saloon is on the main deck, many feet above the water line, and with broad windows on both sides, affording outlook upon the waters far and near, it is a most attractive feature. The architectural designs for the finish and furnishing of this saloon are in the full Indian style, with all decorative and ornamental work in accordance. The woodwork is of mahogany, as is also the furniture.

The windows are numerous and of considerable breadth, and with sashes to open from the top or bottom. Between the windows are sideboards as fixtures. Over each window is a section of the electric light system of the saloon, beautifully designed and worked out. The ceiling is finished in beams and straps of mahogany, with panels of most beautiful designs. Each panel has a medallion in the centre, and alternate panels have electric light pendants.

Opening out from the dining saloon are two small private dining rooms, each

having a capacity for seating twelve persons. In the main dining saloon as many as 325 persons may be seated at one time. At the forward end of this saloon are the wine room, silver room, and a special room for the service of tea, coffee and chocolate. The kitchen on this boat is another spacious affair, in which a hundred waiters can be served at one time as they come and go. Still further aft on this deck, and beyond the private dining rooms, is a ladies' cabin, which has another of similar dimensions and uses directly under it on the deck below.

So far as the floor, furniture and general appearance of the walls of the grand saloon are concerned, these do not differ materially from the same features in the *Puritan* and the other great passenger boats of the Fall River Line, with the exception that here, again, there is a marked advantage in the matter of space. The prominent features of this grand saloon are,—a massive and perfectly plain staircase leading to the upper deck; an ornamented bulkhead at the top of this staircase, dividing forward from aft at what may be termed amidships of the gallery deck; and a system of electric lighting that blends the artistic with the practical.

Heretofore, very much of the decorative work in elaborately finished rooms in costly houses, and especially upon vessel interiors, has been shown upon the wood surfaces, which, in the nature of things, must, in the course of time, crack or warp to some degree. In the *Priscilla* the ceilings, and in many parts the walls, of the saloons and rooms are covered with plates of papier maché at least a quarter of an inch thick. These plates are sufficiently elastic to conform to slightly convex or concave surfaces, although, in the main, they are as stiff and firm as wood finish.

This material, thus prepared, receives, readily, ornamental or decorative work, or it may be cast in designs and figures desired for these purposes. Some of the papier maché plates used on the *Priscilla* are many feet in area, varying in shape to meet the exigencies of their employment. Work done in this way will stand indefinitely, and a very fruitful source of vexations and disappointments is by these means avoided.

The principal feature of the electric lighting apparatus of the grand saloon is in the form of an inverted dome, dependent from the ceiling half way between the bulkhead at the head of the gallery staircase and the mast which is nearly central. This dome is constructed of metal ribs or bars, running from base to apex, and holding in place sections of opalescent glass, a material, by the way, which enters largely into the lighting system in every part of the boat. Within this dome are fifty electric lights, and running away from it, forward and aft, are lines of opalescent pendants.

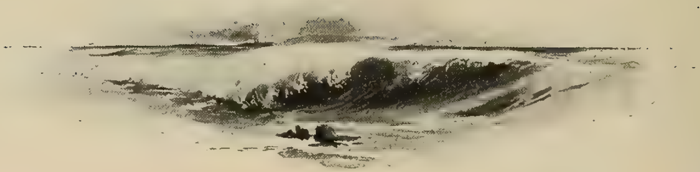
CONSTRUCTOR AND SUPERVISOR OF THE FALL RIVER LINE.

Every device for the safety and comfort of the passengers has been used. Not only does the vessel carry 1700 life preservers, twelve life rafts, and twelve life boats, but there are in each room, and other places, thermostats to indicate unusual heat, and almost every possible

appliance for the protection of life and property. There are on board 1900 electric lights, and forty-five miles of electric wire were used in this service. A person going on board at the regular passenger gangway, passing through all the saloons and around all the decks, walks one and one-eighth miles before returning to starting point. The *Priscilla's* crew consists of 230 men.

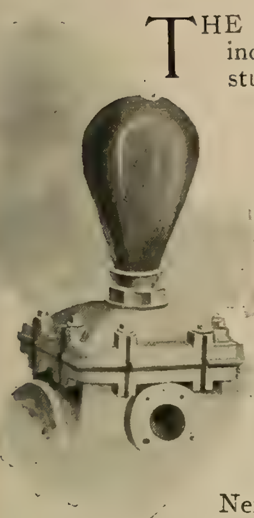
The record for safe transportation of millions of people by the Sound lines of steamers cannot be excelled, the Fall River Line having carried thousands annually for many years without serious injury to any. The engines for these new steamboats were built by the W. & A. Fletcher Company, of Hoboken, N. J., the builders of more engines for steamboats on the Hudson river and Long Island Sound than any other company, and whose acquaintance with this class of work reaches from the smallest to the largest engine.

Many minds laboured with the problems presented, but all views were finally subjected to the judgment of Mr. George Pierce, the constructor and supervisor of the Fall River Line, and these boats bear record to his faithful efforts in accomplishing all that could be desired.



THE AUXILIARY MACHINERY OF AN AMERICAN WARSHIP.

By F. Meriam Wheeler, M. Am. Soc. M. E.



THE modern warship is indeed an interesting study, as it comprises so many industries, —in fact, a naval vessel might be called a fortified city afloat. From the mammoth high-powered guns down to the so-called "donkey" steam pump, it takes in almost everything necessary for the development and preservation of the best fighting qualities of a large force of men.

Next to the main engines and boilers the auxiliary machinery of such a vessel is entitled to the greatest care and attention in order to maintain the highest efficiency and economy. The selection and successful installation of such machinery requires experience and a keen perception of what will best fulfill the requirements embodying reliability, durability, minimum weight and space, and, last but not least, economy in operation.

The derangement or failure of any one of the important auxiliary engines would incapacitate, if not entirely cripple, a warship,—a matter of the greatest concern in case of a storm at sea or during an engagement. The trite saying, "The strength of a chain is measured by its weakest link," can never be better applied than to the smallest auxiliary engine, if upon such the main machinery or gun equipment is dependent.

In order to give a comprehensive and systematic treatment of this subject, the writer will describe the auxiliary machinery of one of the latest and best specimens of modern warship, namely, the United States battleship *Massachusetts.* While this vessel, no doubt combines the most approved practice, up to date, in marine engineering and naval architecture, improvement still goes on, and battleships will, undoubtedly, be designed at no distant day even more powerful and efficient than this particular one.

There are three classes of steam auxiliaries to be considered in this article:— First, those that form a part of the propelling machinery; second, those which are necessary for maintaining the health of the crew; and, third, the machinery necessary to operate the guns and other fighting equipment.

The *Massachusetts* is provided with twin screws; consequently, there are two main engines, each of the triple expansion type, with a combined capacity of about 10,000 I. H. P. To furnish steam for these engines and the steam auxiliaries throughout the ship there are four double-ended main boilers and two single-ended auxiliary boilers, carrying a steam pressure averaging 160 pounds per square inch.

To provide for the large number of auxiliaries that are used on a war vessel like the *Massachusetts*, there must be a special system of steam and exhaust piping, so arranged as to secure the greatest flexibility of use under certain possible conditions. In the case of this ship, the auxiliary steam pipes extend nearly the whole length of the vessel and are so connected by valves that steam can be taken from either the main or the auxiliary boilers. The exhaust pipes for the auxiliaries are arranged to conduct the exhaust steam from them, (*a*) to the receivers of the main engine; (*b*) to the main condensers; (*c*) to the auxiliary condensers; or, (*d*) to the

A BOW VIEW OF THE "MASSACHUSETTS."

open atmosphere, as desired. There are no pump connections whatever attached to the main engines; hence, all the power developed by the latter is utilised in propelling the vessel.

Each of the propelling engines is furnished with a surface condenser, having 6355 square feet of tube surface. The condensing water is drawn from the sea and forced through each condenser by a centrifugal circulating pump, driven by a simple engine 12 inches in diameter by 6-inch stroke. This engine has a direct connection with the pump wheel or fan, which latter is 32 inches in diameter.

In case of emergency the two circulating pumps can draw water from the bilges, and discharge either overboard or through the condensers, or both. The suction and discharge pipes of each circulating pump are 15 inches in diameter.

The original specifications of the United States Navy Department for the machinery of the *Massachusetts* contemplated the use of independent air pumps of the crank and fly-wheel type, the air pumps to be connected by a gearing to the steam cylinders. Later on, however, experience proved that the fly-wheel arrangement of air pumps was neither as reliable nor as efficient as the vertical direct-acting Blake "twin" system, such as had been furnished for the United States cruisers *New York*, *Columbia*, *Minneapolis* and *Brooklyn*, and the other battleships building at the William

Cramp & Sons Ship and Engine Building Company's works. The Bureau of Steam Engineering of the Navy Department, therefore, approved of the recommendation of the Cramp Company to adopt similar direct-acting air pumps for the *Massachusetts.*

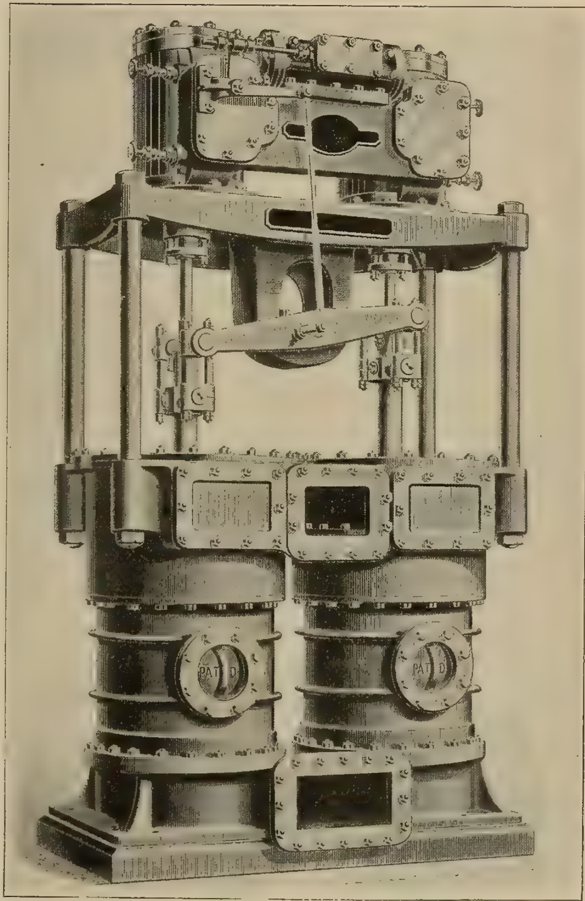
As shown on this page, the steam cylinders of the air pump are directly over the air cylinders. The beam which positively connects the main piston rods of the pumps, operates (from a point near its centre, and by means of a rod and bell crank) the slide valve of the horizontal auxiliary cylinder, which lies between the main steam cylinders. The piston of this cylinder is really the driving engine for the main cylinder steam valves, a function which it performs by means of a system of internal levers.

The operation of the pump is not only decidedly positive, but is very regular and uniform. The adjustable collars shown on the valve stem of the "valve-driving engine" afford a means for ready adjustment for a full stroke even while the pump is in operation, while suitable cushion valves give a further control over the action during each stroke, in regulating the distribution of work and preventing slamming of the foot valves.

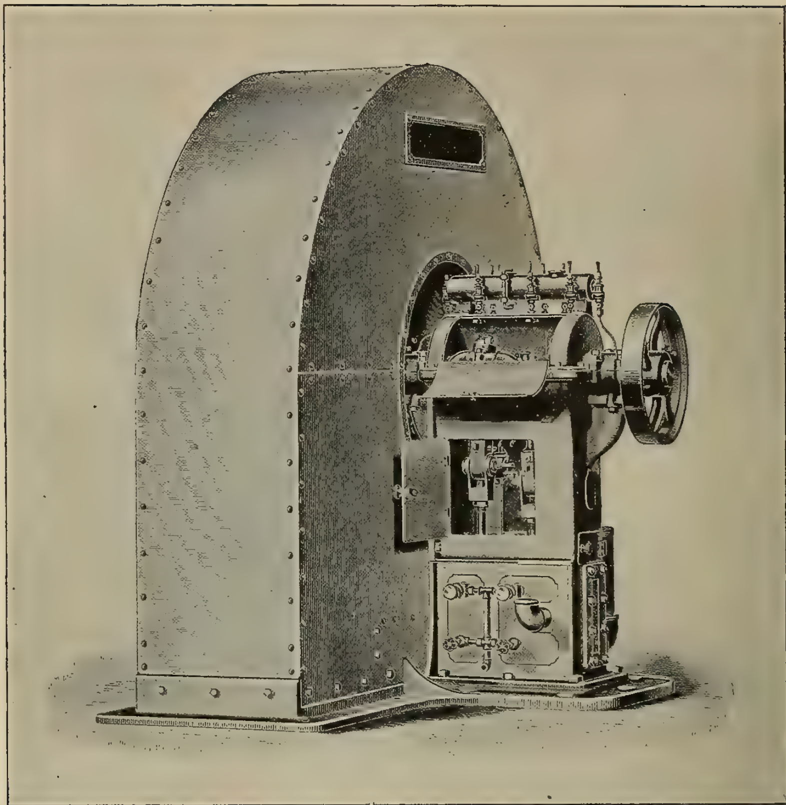
The air cylinders are of the usual single-acting type, provided with foot, bucket, and head valves. The design of this pump combines minimum amount of floor space and weight. On the official trial trip of the *Massachusetts* the air pumps did their work at a speed averaging less than seventeen double strokes per minute, maintaining a vacuum of over twenty-five inches. The indicated horse-power of these pumps was only about one-eighth of 1 per cent. of that of the main engines, —a remarkable showing.

Referring to similar pumps on the *Minneapolis*, the official report on the trial trip of that vessel speaks of the "twin" air pumps as follows:—

"The operation of the main air pumps simply emphasised the justice of the claim of this class of pumps for highest honours. Not only did they do remarkably efficient duty at the smallest cost in power, but the regularity and certainty of their action, and their low speeds conduced to other efficiencies by reducing to a minimum all anxiety on

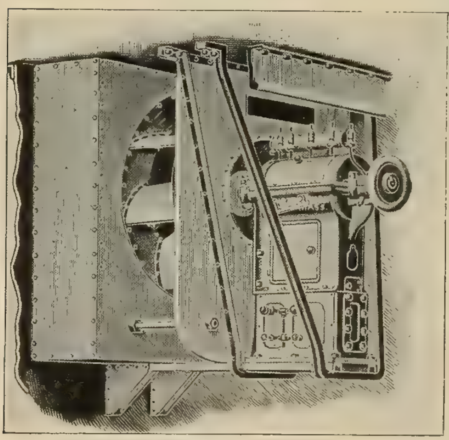


A BLAKE TWIN AIR PUMP. BUILT BY THE GEO. F. BLAKE MFG. CO., LONDON AND NEW YORK.



BLOWING OUTFIT FOR VENTILATING THE ENGINE ROOM. MADE BY THE B. F. STURTEVANT CO., LONDON AND BOSTON.

the part of those in charge of the running of the machinery regarding their



A STURTEVANT BLOWER FOR FORCED DRAFT.

possible stoppage or breakdown, or of sudden and excessive change of speed. Those who have had experience with the crank air pumps (however well they may be made, in theory, to operate), cannot fail of comfort in the knowledge of the adoption of the Blake vertical twin-cylinder air pump for our latest cruisers. Here, at about only fifteen double strokes per minute, these pumps maintained a steady vacuum of over twenty-five inches, at a cost of but little more than thirty horse-power for all three double pumps, and with the main engines aggregating over 20,000 horse-power. This power of air pump is only about one-sixth of 1 per cent. of the horse power of the main engines."

The principal dimensions of each of the air pumps on the *Massachusetts* are as follows:—Steam cylinders, 12 inches

diameter by 18 inches stroke; air cylinders, 25 inches diameter by 12 inches stroke.

In each engine room there is provided a vertical duplex pump of the Blake (Admiralty) type, 12 × 7 × 12 inches, which can be used to pump either from the sea, the bilge, the secondary drainage pipe, the drainage cistern, the feed tank or the air pump suctions. It is also connected so as to discharge into either the main or auxiliary feed pipes, the fire mains or overboard, as desired. The capacity of each of these pumps is 400 gallons per minute.

There are also in each engine room two pumps of the same size and make, and another pump of similar type but of smaller size, which draws its supply of water from the sea and delivers it into the water surface pipes and fire mains. The size of these pumps is 8 × 5 × 12 inches, with a capacity of 200 gallons each. In the port engine room there is a distributing oil tank, supplied from the main oil tanks by a small duplex pump.

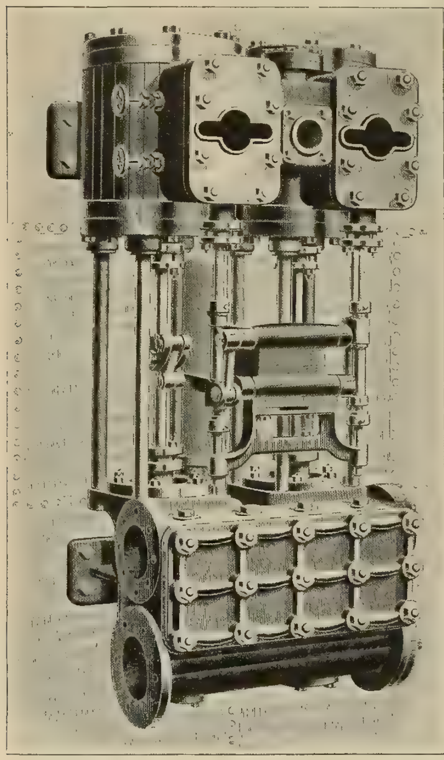
Turning to the subject of the auxiliaries for the boilers, among the most important machines are the pressure blowers. Of course, it is understood that all the boilers are placed in air-tight fire rooms in order to operate them under forced draft. In the fire rooms of the main boilers there are eight blowers, suspended from beneath the deck, each blower having wheels 5 feet in diameter and 14 inches wide at the periphery, and each wheel being directly driven by a double upright encased engine, having steam cylinders 5 inches in diameter by 4 inches stroke. Each of the blowers takes its supply from above decks through an inside air duct and delivers a current of air into the fire room in which it is located. The blowers for the auxiliary boilers have wheels 36 inches in diameter, with a width of periphery of 12 inches, and are each driven by double engines, 3½ inches in diameter by 2½ inches stroke. The general design of these blowing engines is shown on the opposite page. Upon the official trial trip these blowers maintained an average pressure of 0.993 inch of water, at a speed of about 399 revolutions per minute.

For the ventilation of each engine room there is provided a blower having a wheel 4 feet in diameter, driven by a double-connected upright engine with

THE FORWARD DECK OF THE "MASSACHUSETTS."

steam cylinders 4 inches in diameter and 3 inches stroke, the design of which is shown on page 486.

For feeding the boilers there are placed in each fire room two vertical duplex pumps of the Blake (Admiralty) type, one for the main, and the other for the auxiliary feed connections. The main feed pumps take their supply from the feed tanks located in the engine rooms, and deliver solely to the main boilers. The auxiliary feed pumps are arranged to draw from (*a*) the same feed tanks, (*b*) the bilge, (*c*) secondary and drainage pipes, and deliver into the



A BLAKE ADMIRALTY FEED PUMP.

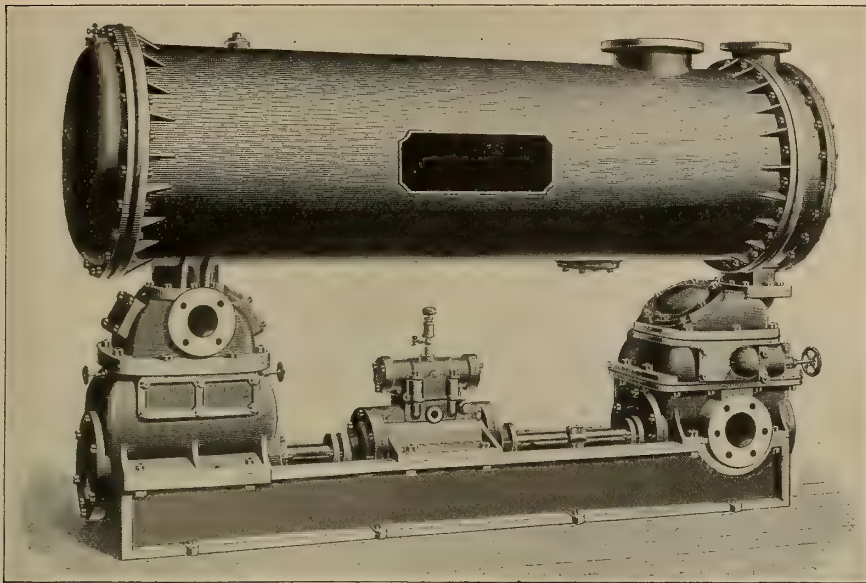
feed pipes, the fire mains or overboard, as desired. Both main and auxiliary feed pumps are of the same size, namely, 12 × 7 × 12 inches, and are shown above.

In each of the fire room hatches there is placed a Williamson Bros. double reversible ash-hoisting engine, each of which has sufficient power and capacity to hoist 300 pounds of ashes from the fire room floor to the deck above in five seconds' time. The valve gear is operated by a small hand wheel, and as this wheel is revolved by the operator, the engines can be regulated to any speed desired. Adjustable stops are provided to limit the hoist and the drop of the ash bucket. Each of the steam cylinders of these ash hoists is 4½ inches in diameter by 4½ inches stroke. One of these engines is shown on the next page.

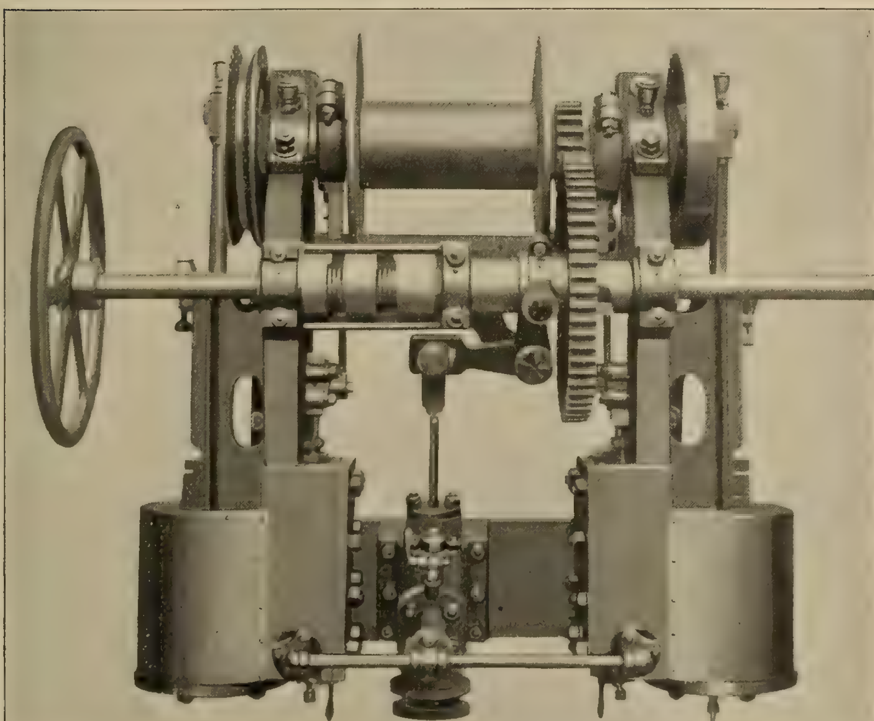
In each engine room there is placed a Wheeler auxiliary surface condenser, provided with, and mounted upon, a Blake air and circulating pump, having an 8 inch steam cylinder, a 9 inch air cylinder, 9 inch water cylinder, and of 10 inches stroke. Each of these auxiliary condensers has 400 square feet of cooling surface. This arrangement of mounting the condenser upon the air and circulating pumps makes a very compact machine and saves the usual piping between the discharge of the water cylinder, the suction of the air cylinder and the condenser. The illustration at the top of the page opposite represents one of these condenser outfits. The use of auxiliary condensers on a vessel admits of the operation of any or all of the auxiliary engines while the ship is in port, or lying-to in heavy weather.

The foregoing, together with pumps for water service, oil, etc., comprises the principal auxiliaries upon which the main propelling engines and boilers are dependent. It might be mentioned here, however, that each main engine is fitted with a steam reversing engine, and also with a steam turning engine for convenience in turning the main engine over should occasion require it when steam is down. For making ordinary repairs the ship is provided with a small machine shop engine for driving the machine tools necessary.

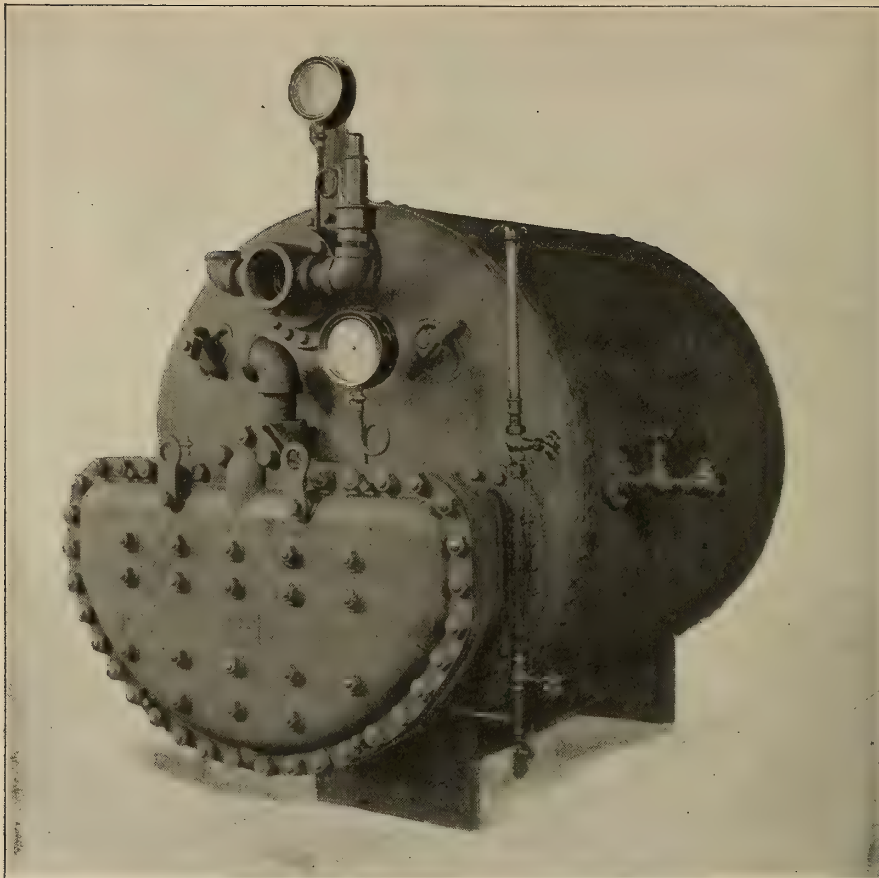
The *Massachusetts* is furnished, like most of the large United States war vessels, with distillers and evaporators in duplicate, these being of the Baird system, and having a maximum capacity of 5500 gallons of potable water per twenty-four hours, the ordinary capacity



AN AUXILIARY SURFACE CONDENSER, MOUNTED ON COMBINED AIR AND CIRCULATING PUMP.
MADE BY THE WHEELER CONDENSER AND ENGINEERING CO., NEW YORK.



AUTOMATIC ASH HOISTING ENGINE. BUILT BY MESSRS. WILLIAMSON BROS., PHILADELPHIA, PA.



A BAIRD EVAPORATOR. MADE BY THE M. T. DAVIDSON STEAM PUMP WORKS, NEW YORK.

being 4000 gallons. This distilling apparatus is provided with Blake pumps and suitable attachments to readily convert the water from the sea into fresh water for supplying the boilers, and for the use of the crew.

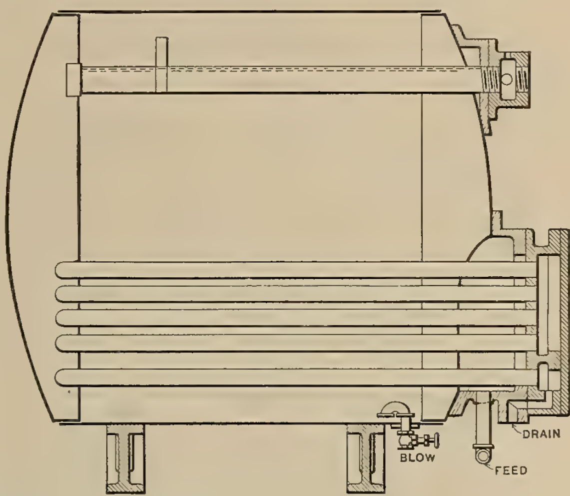
For ventilating the ship generally there are provided four Sturtevant blowing engines, each having 4-foot wheels and driven by engines 4 inches in diameter by 4 inches stroke, of the upright type,—the design being similar to that of the engines used for ventilating the engine rooms. These blowers are so designed that air may be drawn from the outside atmosphere and forced through the ship, or *vice versa*, as desired.

On the after platform deck there is a Williamson steam steering engine, which may be operated either from the bridge, the pilot house or the conning tower, by means of wire rope connections from the hand-steering wheels to the operating valves of the engines. In addition to these forward steering stations there is one on the after deck and one below at the steering engine. Both engines are geared sufficiently to steer the vessel by hand should an accident occur to the steam part of the apparatus. There are two steam cylinders to each engine, each 13 inches in diameter by 10 inches stroke, sufficiently powerful to put the helm hard over from amidships in ten seconds' time. There are also four double-cylinder steam reversible winches situated on the main deck, two

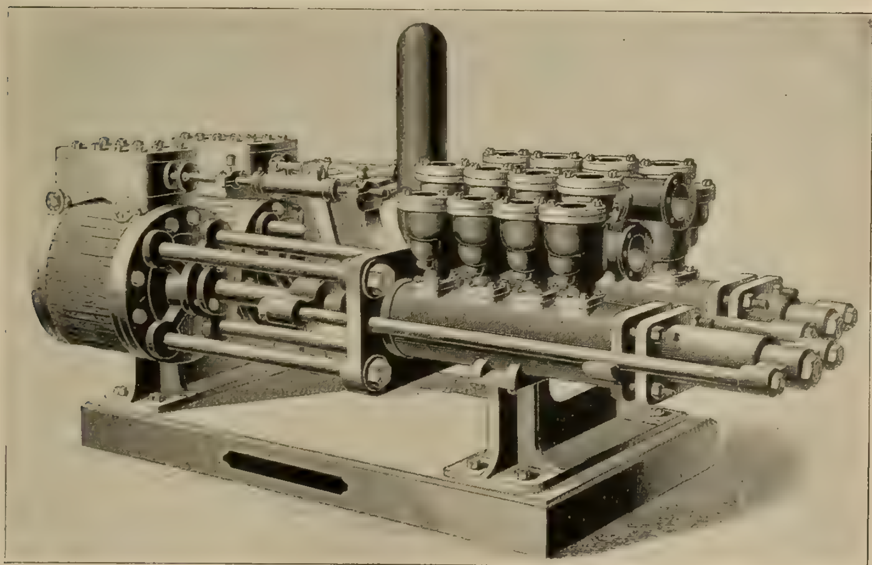
forward and two aft. Each has one drum for wire rope and two gypsies for hawsers. There are also two similar winches situated on the superstructure deck for hoisting boats, the cylinders measuring 8 x 8 inches.

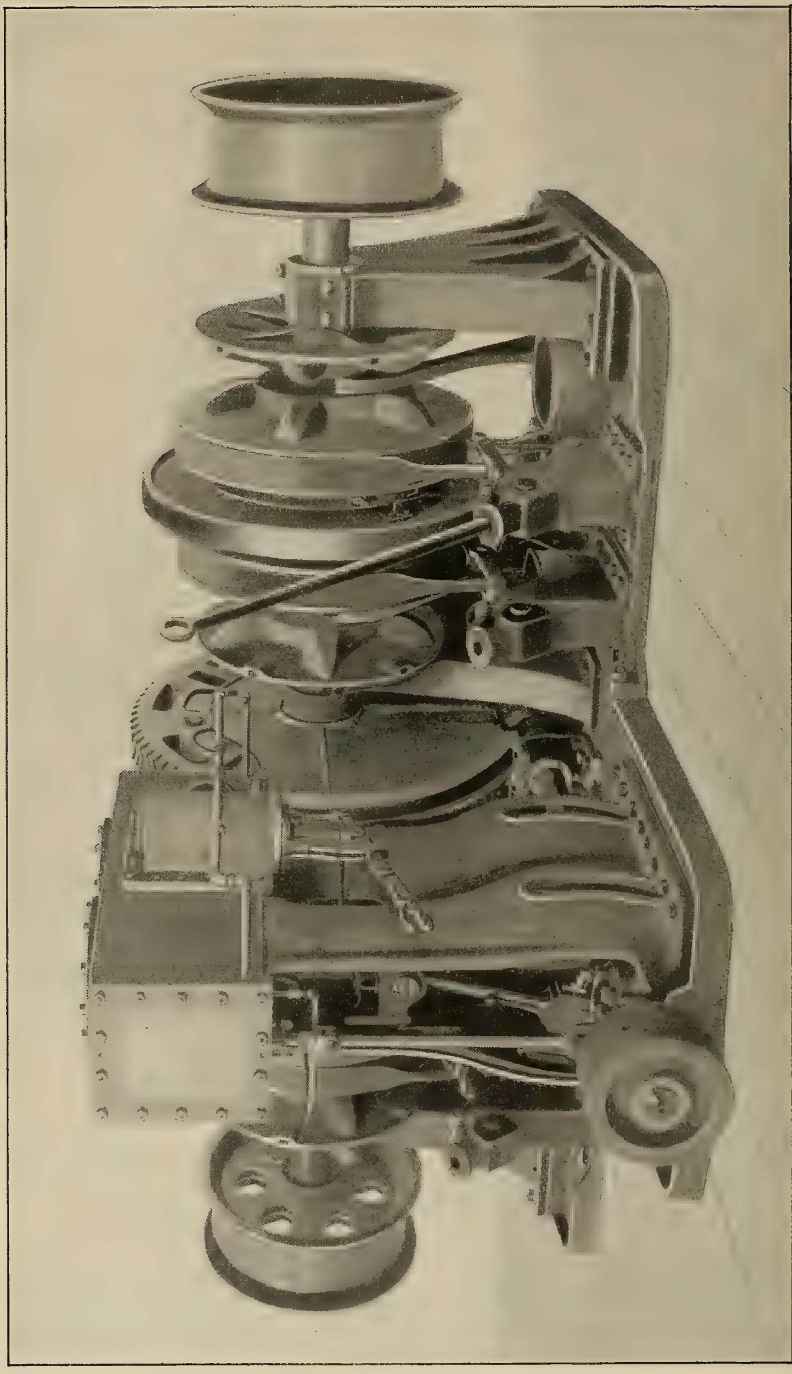
On the main deck forward there is a steam windlass, shown on page 492. This is capable of raising two bower anchors at once, at the rate of six fathoms per minute. The chain stoppers are of the naval type and made of open hearth steel. The deck space occupied by the bed plate is about 120 square feet. The windlass is driven through worm gearing by a double, inverted, reversing steam engine, with steam cylinders 15 inches in diameter by 14 inches stroke. The height of the engine above the deck is only about seven feet. The windlass is provided with four "wild cat" chain grabs, each one fitted to 2½-inch stud link chain.

These are loose upon the shaft, provided with improved locking gear, and controlled by a powerful friction band brake for use in lowering. The chain indicators show the amount of chain payed out, the dials being placed outside the windlass room. An auxiliary hand drive is provided in the pump-brake clamp wheel, and by the toggle arrangement any amount of chain may be raised by hand power applied to the pump brake levers on the deck below. There is



SECTIONAL VIEW OF A BAIRD EVAPORATOR.





THE STEAM WINDLASS ON THE "MASSACHUSETTS." BUILT BY THE AMERICAN SHIP WINDLASS CO., PROVIDENCE, R. I., U. S. A.

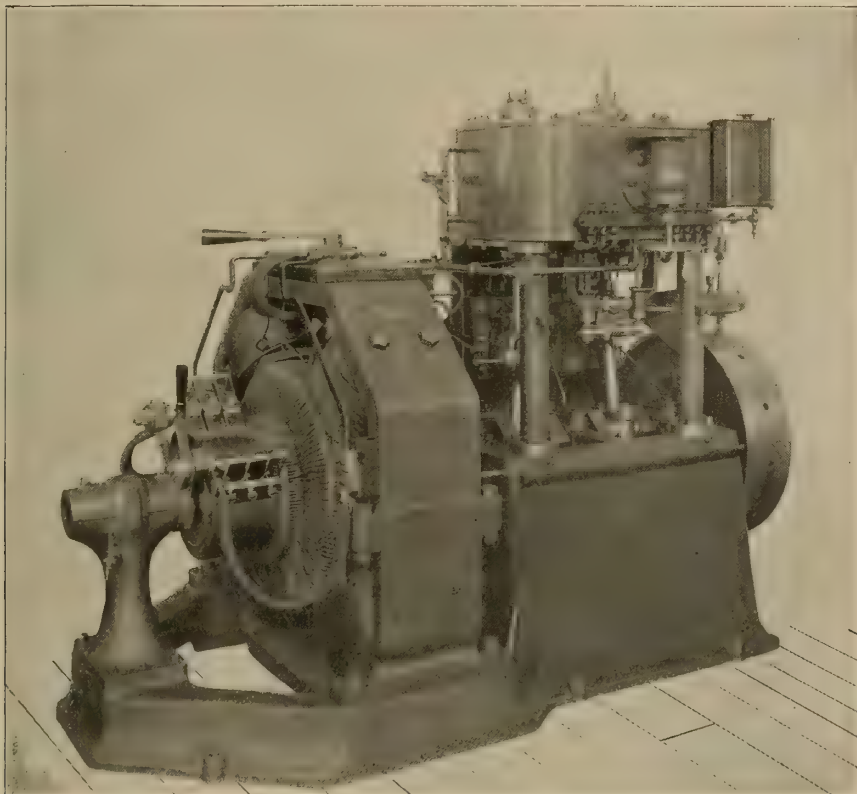
also a drum on each end of the windlass that can be used for various purposes, independent of hoisting the anchor.

Referring to the fighting equipment of the *Massachusetts*, each of the turrets for the 13-inch guns is turned by a double horizontal engine with cylinder 11½ inches in diameter and 10 inches stroke, one engine being located in the compartment forward of the boilers, and the other in the compartment abaft the engines. These engines turn the turrets through the medium of shafting and gearing through an angle of 270 degrees, and automatic stops are provided to prevent this limit being exceeded.

Each of the turrets for the 8-inch guns is turned by a double vertical engine with steam cylinders 8 inches in diameter by 7 inches stroke, located in the ammunition passages on the orlop deck. All the turret turning engines are operated from the sighting hoods of the turrets.

The hydraulic plant for raising and lowering the 13-inch guns, hoisting the ammunition and other service, consists of two Blake horizontal duplex pumps, arranged with outside-packed water plungers, an accumulator, water tank and the necessary pipes and fittings. The combined capacity of these two pumps is 1000 gallons of water per minute, the working hydraulic pressure being 600 pounds per square inch.

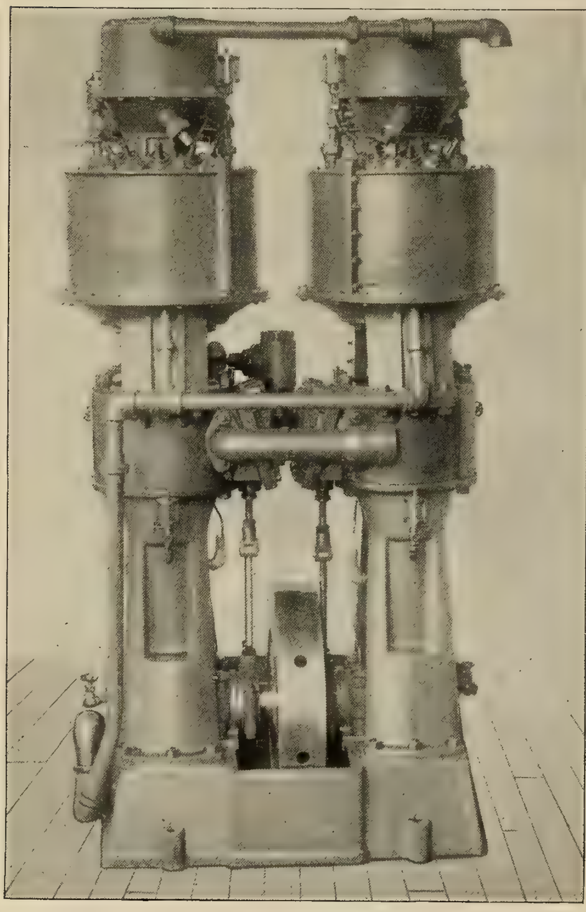
The operation of the pumps is perfectly automatic, being controlled by the movement of the piston of the hydraulic accumulator. The water ends of these two hydraulic pressure pumps are made



ELECTRIC GENERATING SET. A DOUBLE-CYLINDER, 10½" × 5". ENGINE, COUPLED DIRECT TO A 24 K. W., 80-VOLT. GENERATOR. SPEED, 400 REVOLUTIONS. MADE BY THE GENERAL ELECTRIC CO., NEW YORK.

entirely of composition, as, in fact, are all of the pumps on this vessel, and are tested to 2000 pounds per square inch. As shown on page 491 the valves are located in pots and are readily accessible through convenient hand holes. The pumps have 24-inch steam cylinders; 8-inch water plungers, and 12 inches stroke. The hydraulic accumulator has an 8-inch steam cylinder, a 28-inch water plunger, by 30 inches stroke, and a water plunger 10 x 30 inches.

The electric lighting plant is one of the very latest type as furnished by the General Electric Company, of New York, and consists of three so-called "Government Standard," 24 kilowatt generating units, with dynamos of the multipolar type, each having a capacity of 300 ampères at 80 volts. The engines driving the dynamos are of the two-cylinder inverted vertical type, 10½ inches in diameter by 5 inches stroke, and are designed to run at 400 revolutions per minute. The weight of each generating unit, comprising engine, dynamo and bed plate, is about 8500 pounds.



THE AIR COMPRESSORS FOR TORPEDO SERVICE. BUILT BY THE RAND DRILL CO., NEW YORK.

Including these generating units, the installation consists of 500 incandescent lights, four search lights, one set of signalling apparatus, two stationary ventilating fans, driven by electric motors, four portable ventilating fans driven by electric motors, four electric motors for the 8-inch ammunition hoists, one main switch board, together with the necessary wiring fixtures.

For operating the Whitehead torpedoes two Rand air compressors are provided, connected to the torpedo tubes and situated in the orlop deck within the citadel, one forward and one aft. Each compressor has two steam cylinders 9 inches in diameter and of 4 inches stroke. The air cylinders have water jackets. The air is first taken into one cylinder and then passed to the other, where it is compressed up to a pressure as high as 1700 pounds per square inch. The compressors are capable of working up to 200 revolutions per minute with fifty pounds steam pressure.

An Allen dense air ice machine is provided for the vessel's crew. It is capable of making one ton of ice per day, or 200 pounds of ice while keeping the refrigerating rooms near the freezing point and cooling 300 gallons of water to 40 degrees tempera-

A TORPEDO TUBE ON THE "MASSACHUSETTS"

ture Fahrenheit. The operation of this machine is quite novel. Atmospheric air is compressed to about sixty pounds per square inch, the sensible heat resulting from this compression being absorbed and carried away by cooling water supplied from the sea. The air is then expanded in a cylinder fitted with a piston, the compressed air being cut off at a certain point in the stroke and then expanded during the remaining portion. This cut off process maintains the pressure of the air in the pressure pipes, while the air, which has become cold from expansion, passes out into the refrigerating pipes. After becoming heated in its circuit it is returned to the compressors to be again compressed, and cooled by the sea water

A general view of this machine is given on page 497. The dimensions of the machine are as follows:—Diameter of steam cylinder, 7 inches; diameter of air compressing cylinder, 5¾ inches;—air expansion cylinder, 4¾ inches;—circulating water pump, 1⅝ inch; stroke of all, 10 inches.

It may seem to some that there are an unusually large number of steam auxiliaries in a war vessel of this kind. This is apparently so, but it should be remembered that provision must be made for contingencies and accidents, and many of the machines are therefore arranged in duplicate. This practice is commendable, as it would never do to cripple a vessel by any important piece of machinery breaking down. Of course, it makes a large amount of machinery to look after and multiplies very much the cares of the engineering staff. In a warship like the *Massachusetts*, there are altogether eighty-six steam engines, big and little, in the equipment, and many of these engines have double steam cylinders; in fact, there are no less than 158 steam cylinders, all told.

With so many engines to be supplied with steam, it is very apparent that the matter of economy should be carefully studied. This subject has been looked into more or less, but it has been found that to compound the engines of many of the auxiliaries would add still more to the complication, to say nothing about additional weight and space. Then

THE U. S. BATTLESHIP "MASSACHUSETTS." TWIN SCREWS. INDICATED H. P., 0000. DISPLACEMENT, 10,231 TONS. SPEED, 16 KNOTS.
BUILT BY THE WM. CRAMP & SONS SHIP AND ENGINE BUILDING CO., PHILADELPHIA.

again, many of the auxiliaries are only occasionally brought into use. However, there is no doubt that as great a stride will be made in the near future in steam economy for the auxiliary engines as has been done with the main engines.

Although the power of all the auxiliaries on the trial trip of the *Massachusetts* averaged only about 2¾ per cent. of the indicated horse-power of the main cent.; forced draft blowers, 107 I. H. P., or about 1 per cent.; other auxiliaries, 45 I. H. P., or about one-half of 1 per cent. The total of all the auxiliaries was 275 I. H. P., or, as above stated, about 2¾ per cent. of the I. H. P. of the main engines. This certainly shows that there is an opportunity for the designers of the different auxiliaries to try and see if some of this steam can-

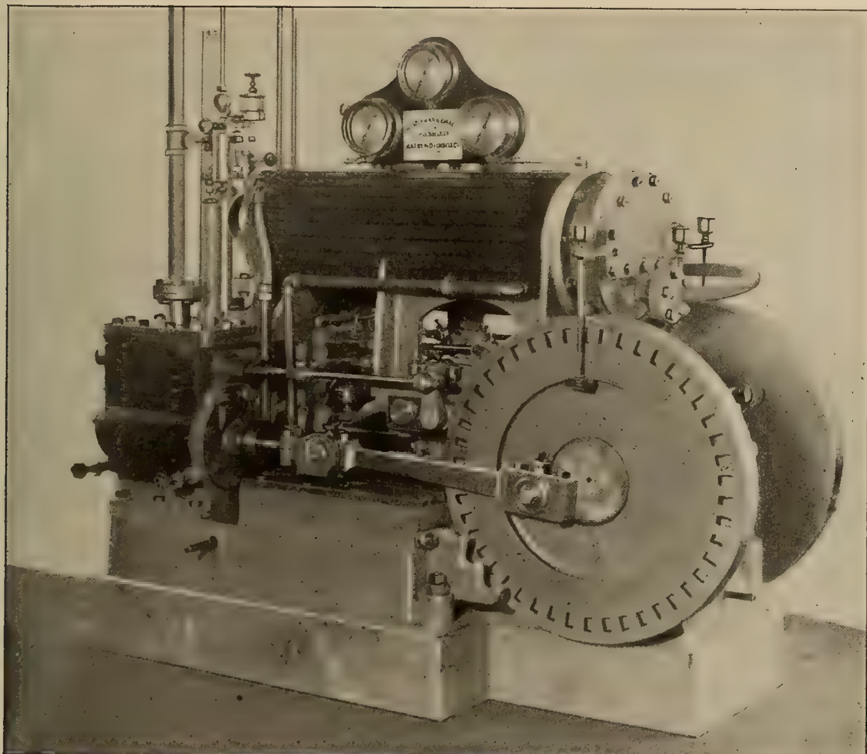


FIG. 14. THE ALLEN DENSE AIR ICE MACHINE, BUILT BY H. B. ROELKER, NEW YORK.

engine, the actual amount of steam used by these auxiliaries was, no doubt, anywhere from 10 to 15 per cent. of all the steam generated. On the trial trip referred to, the main engines and the auxiliaries in use developed the following powers:—Main engines, 10,128 I. H. P.; air pumps, 12½ I. H. P., or about one-eighth of 1 per cent. of the power of the main engines; circulating pumps, 36½ I. H. P., or about one-third of 1 per cent.; feed pumps, 64 I. H. P., or about two-thirds of 1 per not be saved. Of course, where a suitable feed water heater is used, the exhaust steam from the auxiliaries can be condensed by the feed water supply, and nearly all of the rejected heat of such exhaust steam can be carried directly into the boilers.

Although many stationary steam plants, especially large electric light and electric railway systems are not now considered complete without auxiliary feed water heaters, the use of such heaters has so far gained but little foothold

in marine practice. Very frequently, however, the principal auxiliaries are arranged to exhaust into one of the receivers of the main engine, which is a very excellent method of utilising the exhaust from such auxiliaries where the conditions are favourable.

It will be seen from the foregoing that besides the propelling machinery of a battle ship, the auxiliary machinery, if properly adapted and installed, becomes one of the most powerful agents in the event of a naval engagement, not only in handling her guns and other fighting equipment, but in furnishing all sanitary facilities, necessary for maintaining the health and comfort of those on board. In fact, such advantages are the best safeguards against dissatisfaction among the crew, and tend to make a vessel quite a desirable place in which to live and work.

SHIPBUILDING AND TRANSPORTATION ON THE GREAT AMERICAN LAKES.

By Joseph R. Oldham, N. A.

WHILST the fierce and ever memorable struggle was being waged in the United States, between the North and South, it may appear strange to relate that perhaps the most honourable and civilising enterprise of modern times was being launched in the troubled world of commerce not many hundreds of miles away from the actual scenes of battle.

It was in the year 1862 that Mr. J. C. Evans, of Buffalo, N. Y., commissioned the veteran shipbuilder, David Bell, of the same city, to build for the company now known as the Anchor Line, the first iron merchant vessel that ever floated on the Great American Lakes. This vessel, the *Merchant*, was a screw steamer of about 200 feet length and her dead-weight ability equalled about 700 tons.

Though her capacity was small, her gross earnings could not have been insignificant, for when carrying flour and bacon from Chicago to Collingwood in those days, not less than from $7 to $10 per ton was received; twenty-five cents per bushel was not an uncommon price to be paid for the transportation of wheat from Chicago to Buffalo. As the *Merchant* could carry about 35,000 bushels, her freight would often amount to over $8000.

Though the modern successors of the *Merchant* can carry seven times the amount of cargo, it is doubtful whether an eight-thousand dollar freight has yet been credited to one of the large modern steamers for a voyage of equal distance. I have not been able to learn what the *Merchant's* hull and machinery cost, but she was the first iron vessel, and, I believe, also the first cargo boat on the Great Lakes, to burn coal under her boilers.

The next decided step in the evolution of lake shipbuilding was consummated by the building of the iron steamer *Onoko* at the Globe shipyard, at Cleveland, in the year 1882. She was 282 feet long and has carried over 2000 gross tons down the St. Mary's river. To show the great economy effected in the production of mild steel and in the steamships constructed of that material, I may say that ten years ago it cost fully eight cents per pound of iron in a steamer's hull to construct her; to-day the best steel vessels can be built on the lakes for a total cost of about four cents per pound of metal in the hull.

Ten years ago a large steamer cost fully $95 per ton dead-weight ability; to-day large steel lake steamers may be bought for less than half that money. If proof were needed, surely this would show that there is a most progressive maritime community on these inland seas. The number of iron and steel vessels on these lakes now is 227, or about 450,000 register tons.

One hundred and seventeen vessels of 108,782 tons were constructed on the Great Lakes during the twelve months which ended last June. This is equal to about half the tonnage built on the

Wear in twelve months, for during the last nine months 172,064 tons were launched into that narrow river, corresponding to an output of about 220,000 tons per annum. But it must be remembered that the Wear has the greatest shipbuilding port in the world.

The model, or peculiarities of form, of lake freight steamers is not dissimilar to the ordinary British cargo steamer, though the lake vessels have somewhat less rise of floor. The most striking feature of divergence is that the steamers of the inland seas have their pilot houses, or wheel houses, right forward and their engines right aft; moreover, bar keels and surface condensers are almost unknown. Hatch coamings seldom exceed half a foot in depth and the masts are without sails. The rudders are invariably of the partially balanced type and the boilers are generally carried on a steel platform, situated about ten feet below the upper deck. There is also an absence of derricks and hoisting gear such as is commonly fitted to tramp steamers intended for trading to all parts of the world.

As to structural strength, it is true that there are a few light vessels on the lakes and, may be, one or two weak ones, but there are none so weak as many steamers that were turned out from European shipyards about the year 1870. The modern large lake steamer is quite as heavy and fully as strong as the best type of ocean cargo boat, and the upper bottoms of the latest fresh water steamers are superior in arrangement and strength to any other class of cargo steamers.

Let me here say a word or two about this feature in modern lake vessels.

THE STEAMER "ONOKO," BUILT BY THE GLOBE IRON WORKS, CLEVELAND, O.

The upper bottoms are now all butt-jointed, as lap joints, or butt strap projections, would interfere with the movement of the unloading buckets. In like manner I am of the opinion that the lower bottom also should be flush outside in all directions, so as to slip over the ground without wearing the lap edges and rivets away, and to permit of more economical repairing.

With regard to lap joints, which are only a revival of an old practice, I think it is commendable to a large extent, for it stands for economy in construction and that should never be lost sight of by a shipbuilder or engineer; but unless lap joints in thick

THE "VICTORY," ONE OF THE LARGEST CARGO BOATS ON THE LAKES. BUILT BY THE CHICAGO SHIPBUILDING CO., CHICAGO, ILL. LENGTH OVER ALL, 400 FEET. BEAM, 48 FEET. DEPTH, 28 FEET. TRIPLE EXPANSION ENGINES. CYLINDERS, 23, 38 AND 63 INCHES. STROKE, I. H. P., 1800.

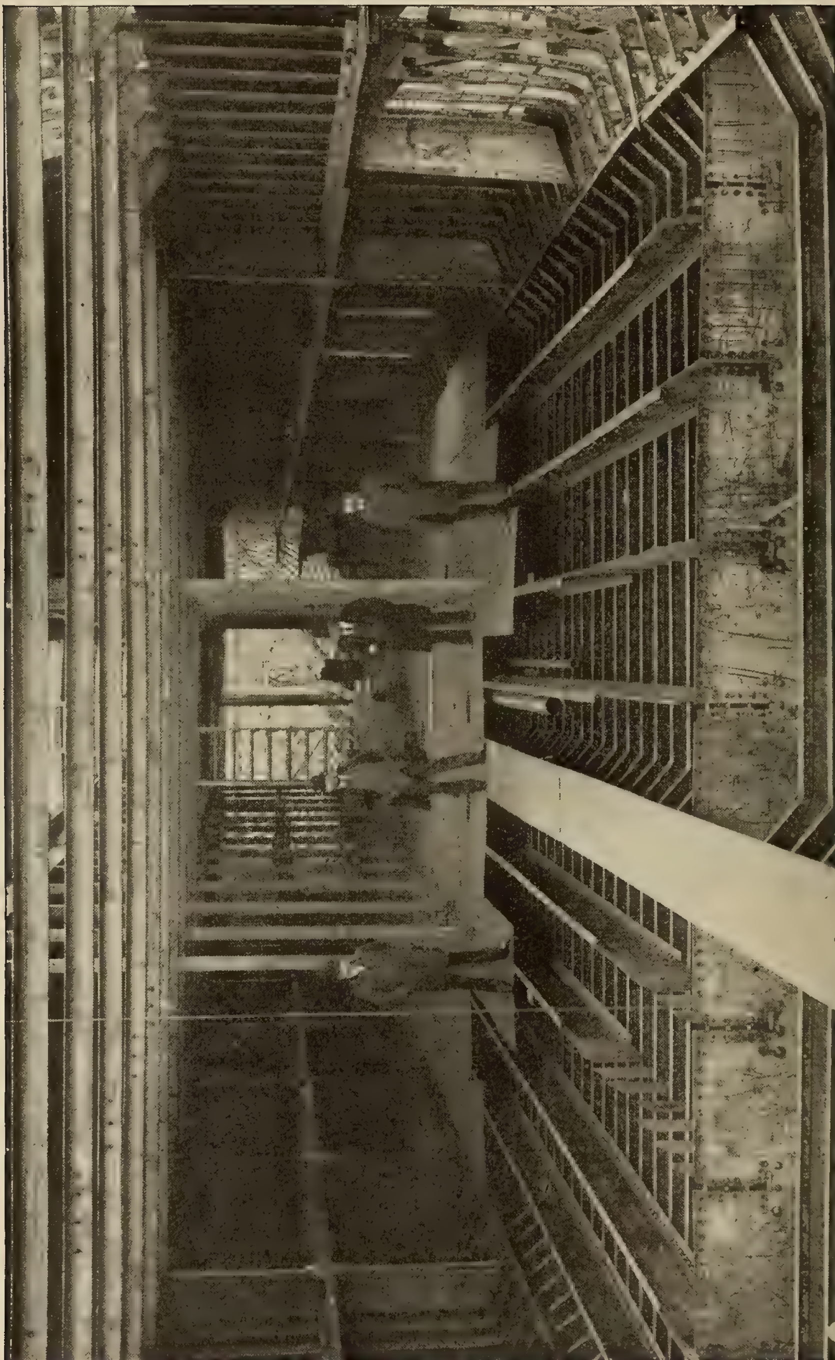
plates are specially arranged, a fair or symmetrical stress cannot be imposed on the rivets. Under any conditions an efficient double butt strap connection is the strongest form of joint, and it should invariably be adopted for the upper stringer and sheer strake plates.

For about four or five years the mean standard dimensions of steamers constructed on these lakes were, length 295 feet, breadth 40 feet, depth 25 feet, and it is remarkable how long shipowners and shipbuilders hovered about these dimensions; but it was the same elsewhere not many years ago. I remember well when but two types of steamers were generally constructed in European yards over a period of four or five years.

The "well deck" type was usually about 250 feet in length, and the flush deck type was about 300 feet long. The former vessels carried about 2000 tons, and the latter, about 3500 tons dead weight. Steamers of just about these dimensions kept the seacoast builders engaged for several years.

The first drastic departure in the building of lake steamers of largely increased dimensions was taken by a young, but enterprising and farseeing shipowner and merchant of Cleveland. The *Victory* was the result of a careful and courageous calculation of financial probabilities and physical possibilities and from that inception may the immediately modern evolution in naval architecture on these Great Lakes be dated. So, passing over small and timid advances in the way of increased capacities of ships, let us see what the absolute and comparative increase of tonnage amounts to since the season of navigation preceding the advent of the *Victory*.

If time permitted, it might be interesting to many if the large lake fleets of oak steamers and sailing vessels were dwelt upon, for amongst the best of these



TYPICAL CONSTRUCTION OF STEEL LAKE STEAMERS. A WHALEBACK FRAME IN THE YARD OF THE AMERICAN STEEL BARGE CO., WEST SUPERIOR, WIS.

may readily be found some of the strongest cargo vessels afloat, and their aggregate tonnage largely exceeds that of the iron and steel steamers; but there is no disguising the fact that metal is rapidly superseding wood as the material of which both large and small craft are being constructed. The paramount reason for this is the rapidity with which wooden vessels decay, whereas iron ships, if kept clean and properly painted, do not rust to a dangerous extent before they become obsolete in design, and valueless as commercial commodities.

Five years ago there was not a vessel on these lakes that displaced 5000 tons when floating on the St. Mary's river. To-day there are not fewer than twenty high-powered steel screw steamers which displace about 8500 tons on the same draft of water. This represents an average increase in the carrying capacity of no less than 70 per cent., and the percentage increase in register tonnage is still higher. Steel cargo steamers, 415 feet in length, and 48 feet in breadth, are now being constructed.

These dimensions are greater than those of the average modern ocean steamer, though several British cargo steamers are about one hundred feet longer and their depth and draft of water is much greater. The carrying capacity of this new lake fleet will equal 3,500,000 tons of ore, transported from the head of Lake Superior to Lake Erie in one season of navigation.

There can be no doubt that the tendency on the lakes is towards larger and larger displacements. As the late Dr. Froude well said,—"Large displacement means larger general dimensions somehow or somewhere." But the limitation of draft of water in small lakes and rivers forbids any considerable enlargement of dimensions, except in the direction of length, for the lake steamers, as commonly designed, are already excessively broad in proportion to depth. A further increased ratio of breadth to depth would involve an objectionably raised metacentre, since stability increases directly as the length and as the cube of the breadth.

THE TOW BARGE "MAGNA," THE LARGEST ON THE LAKES, IN THE YARD OF THE CHICAGO SHIPBUILDING CO. LENGTH OVER ALL, 370 FEET. BEAM, 44 FEET. DEPTH, 26 FEET. CAPACITY, 4000 GROSS TONS ON 11 FEET 6 INCHES DRAUGHT.

As regards the maximum dimensions for safe and profitable lake steamers, I am inclined to the belief that the limit is now about reached. If we go much

farther in the direction of building larger vessels, these might be found unhandy for the narrow and shallow rivers and harbours which they would have to enter sometimes, at least, to get into dry dock. Then, again, it may be a long time before most of the ore docks on the Great Lakes could be converted to accommodate ships with, say, fourteen or sixteen hatchways.

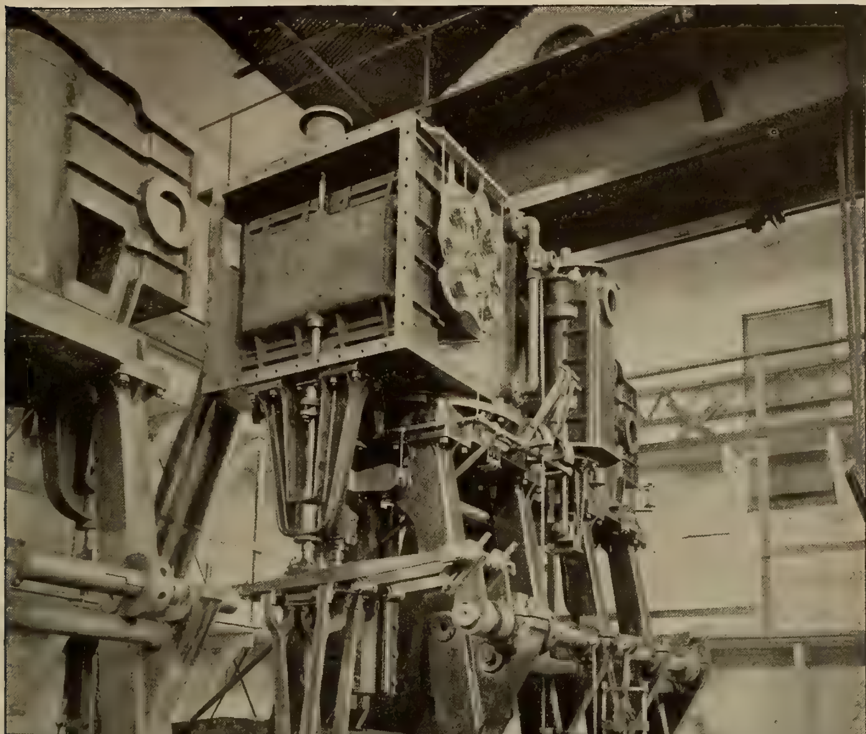
I think it frequently would be more convenient to haul cargoes of seven or eight thousand tons in two parcels rather than one, in which case half of the total load could be taken, say, to Ashtabula, Erie, or Buffalo, and the balance left at Cleveland; and when returning, the steamer could carry hard coal, and her consort soft coal. This brings the subject to the point that it probably will be found more profitable to carry a very large cargo by means of a steamer and a tow barge connected, than by one huge hull in a shallow water trade.

As an illustration of this, consider two very successful vessels, the *Pathfinder* and her consort *Sagamore.* They can carry 7000 gross tons, on seventeen feet draft of water, at the rate of fully ten miles an hour. If that amount of dead weight had to be carried at the same rate of speed in a single large steamer, the latter would have to be 475 feet in length, 50 feet beam and 28 feet in depth. Even then such a steamer could not carry 7000 gross tons of cargo on less than twenty feet of water and I hardly need say that three extra feet draft would be a serious impediment on these lakes. As regards that, a light draft of water is of great value in any trade on the lakes or ocean.

A LAUNCHING SCENE AT THE YARD OF THE DETROIT DRY DOCK CO., DETROIT, MICH.

But another feature of this comparison must not be overlooked. It requires much less effective power to attain a certain speed by a pull of a rope than by propelling by either a screw or side wheels. For instance, the *Pathfinder* and *Sagamore* combined attain an average speed of over ten miles an hour throughout the season with about one-third less horse-power than would be required to propel a steamer of the dimensions quoted, at the same rate of speed.

Against this there is the cost of tow ropes, and I think these vessels use about two twelve-inch ropes, 1000 feet long,



A LAKE STEAMER ENGINE, BUILT BY THE DETROIT DRY DOCK COMPANY, DETROIT, MICH.

A LAKE VESSEL READY FOR LAUNCHING IN THE YARD OF THE CHICAGO SHIPBUILDING COMPANY.

in a season, and one or two more men might be required by the two boats than by one big one; but the net gain is fully 25 per cent. in favour of the two hulls connected by a tow rope. In addition, the first cost is in favour of towing, as one large steamer, capable of carrying 7000 gross tons of cargo, will cost about 20 per cent. more than the combined cost of the *Pathfinder* and *Sagamore*.

With reference to weight of scantlings of ships, I may say that a heavy ship is not necessarily a strong one, and a comparatively light hull need not be weak. For instance, consider two ships of identical dimensions being required to carry the same dead weight; the lighter vessel may be, and frequently is, the stronger when the weight of material is carefully distributed, as a redundance of material may be an element of weakness. This may have been what the late Professor Mosely meant when he said:—"The solid constructed of the strongest form with a given quantity of material is evidently that which can be constructed of the same strength with the least material, so that the strongest form is also the form of the greatest economy of material."

The bottoms of ocean vessels are not generally designed to withstand severe "ashore" strains, and no serviceable cargo ship could be made sufficiently strong to endure pounding on a lea-shore for any great length of time; but it is a question in my mind, whether, in lake vessels, provisions should not be made for lessening the injuries caused by grounding, and for more economical repairing when such injuries are sustained. It must not be supposed from this that the facilities for repairing steel ships are inefficient on the lakes, for such is not the case. Indeed, I am of the opinion,—and I say this after nearly thirty years' experience in superintending the repairs of over 3000 iron and steel vessels, mostly at the best equipped graving docks in the world,—that repairs can be effected, certainly as quickly, and I believe as cheaply, on the Great Lakes as anywhere else.

I fear that slight groundings will not be appreciably lessened in the future, for though immense sums of money are being expended in deepening these shallow rivers and lakes, a deep-type vessel is also being constructed, capable of taking advantage of the greatest depth of

water contemplated, and the splendid new locks on the Canadian and United States banks of the St. Mary's, or "Soo," river will offer no obstruction to vessels drawing twenty feet of water. It is probable, therefore, that the bottoms of the deep steamers will be no further from the ground in the future than in the past, but what with the elaborate arrangements of lights, buoys, stakes and ranges in the "Soo" and Detroit rivers and elsewhere, such casualties may be lessened, and collisions in the first named river will not be so frequent now that the new regulations regarding speed are being rigidly and impartially enforced.

In the year 1852 the improvement of the St. Mary's river began by the construction of a lock with two chambers, each 350 feet long by 70 feet wide, passing vessels with a maximum draft of eleven and one-half feet of water. The first year's freight amounted to 106,296 tons. In 1864 there were passed 1045 sailing vessels and 366 steamers, with a total of 571,438 tons register.

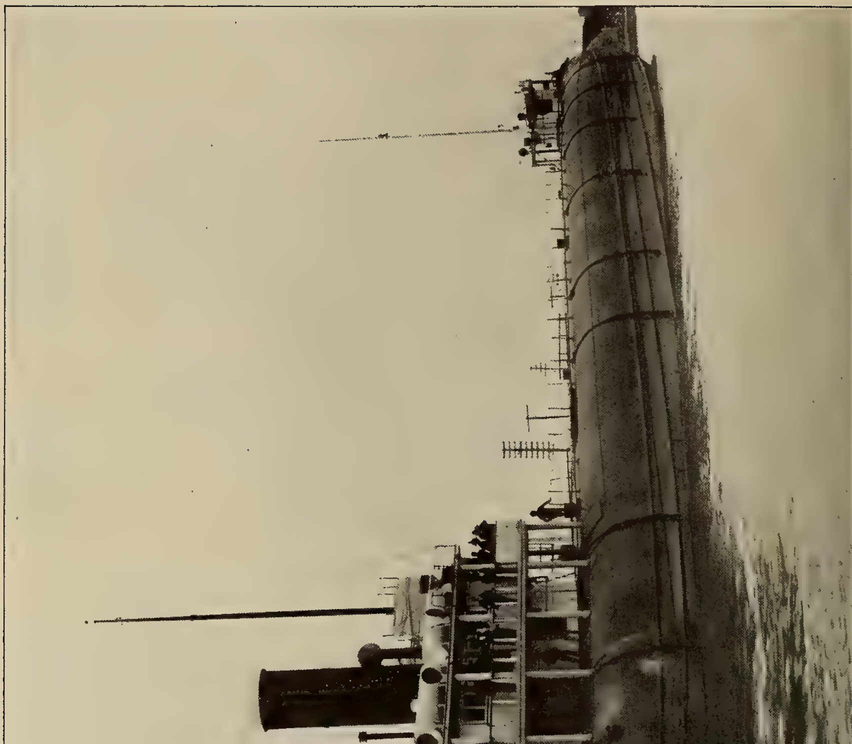
In 1881, the Weitzel lock, which is 515 x 80 x 17 feet over the mitre-sill, was completed. The number of sailing vessels locked through that year was 1706, and steamers, 2117, the aggregate tonnage registered being 2,092,757. In 1893 the number of steamers locked through was 8379, and sailing vessels, 2955, unregistered craft, 774; total, 12,008; aggregate registered tonnage, 9,849,754. In 1894, the number of vessels passed was 13,884, with an aggregate register tonnage of 13,195,860. In 1895 the corresponding figures were 17,956 vessels of 16,806,781 register tons. The total tonnage passing the canal during 1896 was 18,445 vessels of 17,144,385 tons.

The following letters from the assistant engineer, General E. S. Wheeler, and Superintendent J. Boyd, descriptive of the Soo locks and lockage will, doubtless, be interesting and instructive:—

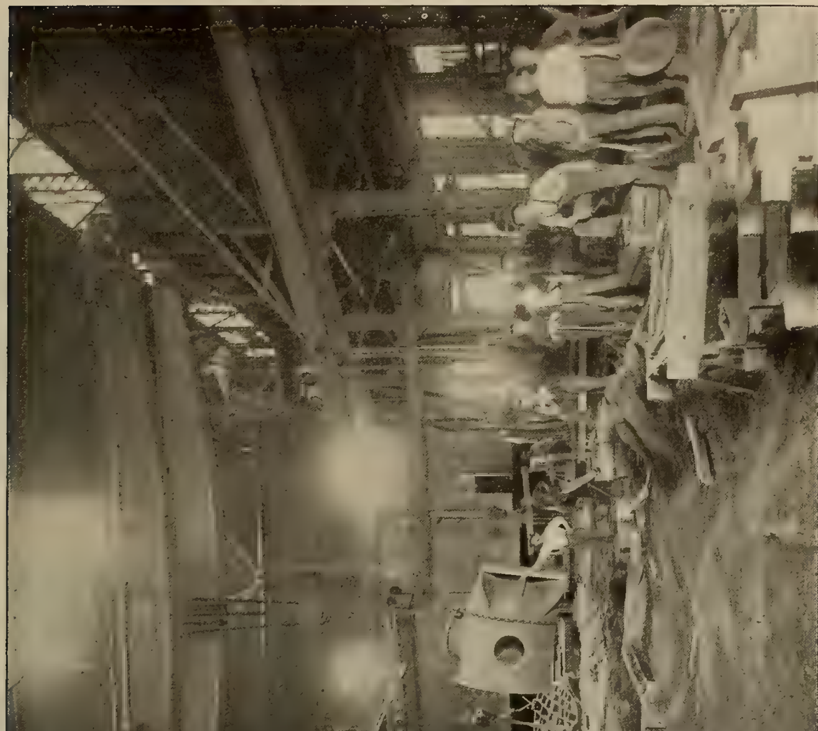
THE STEAMER "YALE," BUILT BY THE CLEVELAND SHIPBUILDING CO., OF CLEVELAND, OHIO, IN ONE OF THE LOCKS OF THE "SOO" CANAL.

"I have your letter of the 6th inst., and would say in reply that the length of the Poe lock between the gates is 800 feet, and the width is 100 feet; the depth of the water over the lower floor and at the lower level is twenty-one and one-half feet at mean stage. The lift at the present time is twenty feet.

"You ask for the shortest time required for a vessel to enter and clear from the lock. This is a very indefinite question. It would be possible for a



THE WHALEBACK STEAMER "PATHFINDER." CARRYING CAPACITY, 7000 GROSS TONS. BUILT BY THE AMERICAN STEEL BARGE CO., WEST SUPERIOR, WIS.



THE FOUNDRY OF THE DETROIT DRY DOCK CO., DETROIT, MICH.

THE LAKE PASSENGER STEAMER "NORTH WEST." BUILT BY THE GLOBE IRON WORKS, CLEVELAND, OHIO. LENGTH, 388 FEET. BEAM, 44 FEET. TWIN SCREWS. QUADRUPLE EXPANSION ENGINES, 7000 I. H. P.

THE MAIN SALOON OF THE "NORTH WEST."

very small and quick-moving tug to pass entirely through the lock in twelve minutes.

"The average time for locking in the Weitzel lock is forty minutes, and the average number of boats in a locking is between two or three. It is expected that the Poe lock will work with about the same rapidity, but it has not been used long enough to obtain an accurate average."

The other letter reads:—

"Your letter of the 6th inst., asking for information in reference to our (Canadian 'Soo') lock, is at hand.

"It is 900 feet long, 60 feet wide, with 20 feet and 3 inches on the mitre-sill at the lowest known water. The average time made in lockage from the opening in September, 1895, up to the end of June last, was twenty minutes; this would include any time that vessels were delayed in the lock by the breaking of the tow line, etc., or something getting on the mitre-sill, and we would have to send down the diver to remove it. Our average off-hand for two vessels would be about fifteen minutes. The fastest that we have on the books was the locking of the steamer *Tilyman* in nine minutes. The C. P. R. steamer *Manitoba* has been put through in eleven minutes two or three times this season."

It is well known that the number of vessel passages through the St. Mary's canal is much larger than the number of vessel passages through the Suez canal per annum, the number of such passages being as follows:—Suez canal 3434 steamers; Soo canal, 17,956. The tonnage of the former is 8,448,246, and of the latter, 16,806,781 tons. Thus, it is seen that the tonnage passing the Soo canal during only seven months of a year is 99 per cent. greater than the tonnage passing the Egyptian canal in twelve months.

It must not, however, be inferred from this that the American lake fleet of vessels is greater than the world's fleet passing the Suez canal. When comparing the tonnage of shipping passing

LAUNCHING A WHALEBACK.

the St. Mary's Falls canal and the African waterway such comparisons cannot but be misleading if the element of time required for the average voyages respectively be omitted from such investigations.

The average steaming time for steamers passing the Suez canal is about sixty days; the corresponding average time for a lake steamer passing the St. Mary's Falls canal is about six days. The average tonnage of the Suez steamers is 2460, whereas the average tonnage of the steamers passing the "Soo" canal is but 950. The mere fact of an aggregation of undenominated tonnage or the numerical transit of passengers

passing a certain point should not be accepted as a measure of the capacity, speed, or value of the vessel property owned by a certain nation or seaport, for, judged by that standard alone, a large New York ferry boat would appear to have about twelve times the capacity of all the Atlantic liners trading to New York city, for such a ferry boat could carry in one month as many passengers as all the Atlantic mail boats disembark at New York in twelve months.

But the comparison commonly made between the " Soo " and Suez canals is in no sense misleading with regard to the freight transported from Lake Superior to Lake Erie, which tonnage is so enormous and so progressive as to render any exaggeration not only unnecessary, but absolutely baneful.

As to navigation on the lake region rivers, —imagine a narrow waterway, say, with not more than 600 feet of channel, fifteen feet deep, and picture two or three steamers, with or without barges in tow, going down the stream at ten or twelve miles an hour, when suddenly, at a bend in the river where a sharp turn of about 90 degrees has to be made, another steamer, or perhaps two, close together, with a string of tow barges, are encountered at the acute turn of the channel.

I say, imagine being placed in that situation both day and night, and the steamer that you have charge of being 50 per cent. larger than the average steamer passing the Suez canal. This is just the ordinary work of American lake captains, or it has been for many years. But now the speed in the " Soo " river is happily limited to nine miles an hour in narrow or shallow reaches and its navigation is not quite so difficult or hazardous.

A sailor who has never seen the " Soo " navigated would probably say that the turns the descending vessels frequently have to make in the face of such obstacles as I have endeavoured to show, are more suitable for one of the picturesque Indians who navigates the St. Mary's rapids with his facile canoe, than for a steel steamer, 435 feet in length and of 8500 tons displacement, yet the task is generally accomplished with safety and precision.

STEEL FOR MARINE ENGINE FORGINGS AND SHAFTING.

By R. W. Davenport, M. Am. Inst. M. E.

AMONG the many parts which go to make up a modern steamship, few, if any, are greater in importance than the moving parts of the steam engine and the long lines of shafting through which the pressure of steam, converted into rotary motion by the engine, is carried to the propeller where, acting upon the resistance of the water, it gives motion to the ship. These parts can be compared to the bone and sinew of the animal frame,—the intermediaries between muscular force and any given resistance.

The principal moving parts of the engine are the pistons, piston rods, cross-heads, connecting rods, valve links and stems, eccentric rods and crank shafts; while each line of shafting consists of the thrust shaft, the intermediate or line shafts and the propeller shaft. All the above parts, with the exception of the pistons, are invariably made of forged iron or steel, which materials insure greater combined strength and toughness than any other at our disposal.

In the early days of marine engine building, forged iron was used exclusively for engine forgings and shafting, the manufacture of large masses of steel being then an unknown art. The property of welding, possessed by wrought iron, made it possible to produce large masses with steam hammers of comparatively small power by a process of building up, by welding together successive pieces of moderate size.

As the production of a perfect weld requires, under the most favourable conditions even when done by hand on a small scale, a great deal of care and skill, it can readily be understood that in welding together successive pieces of considerable size with a steam hammer, thus gradually forming a large unwieldy mass, there is great risk of imperfect adhesion, caused either by lack of heat or other necessary conditions, or by the incorporation, between the surfaces to be welded, of scale or cinders. These imperfections in the homogeneity of the metal sometimes show themselves on the surface in the form of seams or scabs, but are likely to exist in the interior of large masses and are then developed only by fracture when the piece is severely strained. Although it is to be remarked that by great care and personal skill the manufacture of large masses of wrought iron was early brought to a high state of perfection, and that great numbers of forgings have given excellent results in service, nevertheless an element of uncertainty always exists, and becomes greater with the increase in the dimensions and weight of the forgings.

The increase in size of steamships, accompanied by demands for great speed, called for a still larger relative increase in the power to be developed by the engines and transmitted to the propeller, and made it the more imperative to have all parts, and especially those through which the power is transmitted, as perfect and as strong as possible. The possible superiority of steel, as compared with wrought iron, for marine-engine forgings was early recognised by the most advanced metallurgists and marine engineers. It was known that from an ingot of cast steel, forgings could be made practically

BY PERMISSION OF AUGUST BAGEL, DUSSELDORF, GERMANY

UNDER THE 5000 TON HYDRAULIC FORGING PRESS IN THE KRUPP WORKS, AT ESSEN, GERMANY.

homogeneous throughout, and that, in general, steel was stronger and more elastic than wrought iron.

Prior to 1865, however, cast steel was manufactured exclusively by the crucible process, and the production of large ingots, required for heavy forgings, by this process, presented difficulties which few cared to meet, while the cost of such forgings was necessarily so high as to limit their general use in machine structures. Krupp, of Essen, was the leader in producing large masses of crucible steel, and in the London Exhibition of 1851 he showed an ingot of this material, weighing about 5000 pounds, which attracted much attention. In 1873 the same firm exhibited at Vienna a similar ingot, weighing 115,000 pounds.

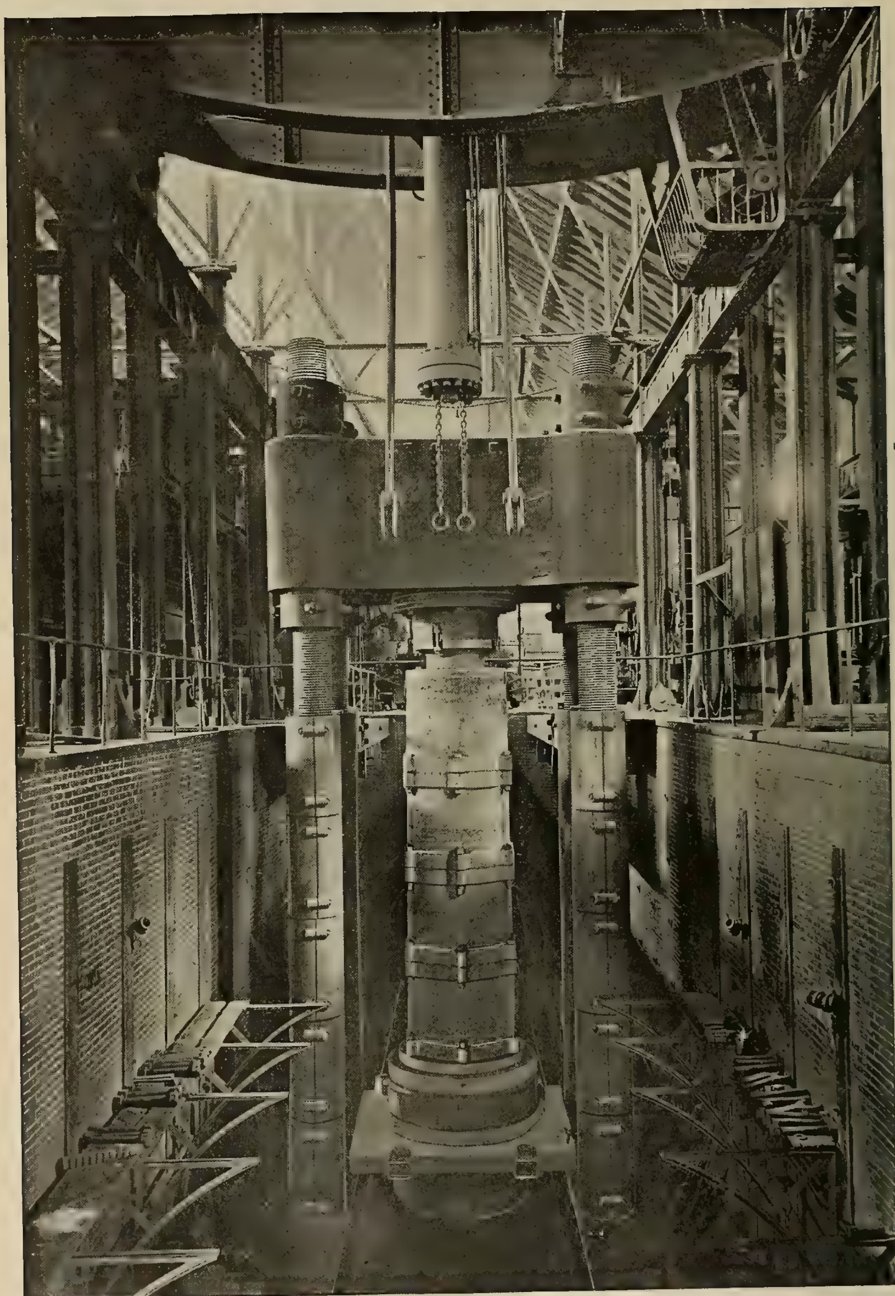
One of the principal uses to which these large masses of crucible steel were applied by Krupp was in the making of heavy steel cannon, in which

he was the pioneer; but the production of large forgings of all descriptions was also rapidly developed with much skill and courage by this well-known firm. The Sheffield crucible steel makers followed Krupp's lead in this direction to a considerable extent.

In the development of the manufacture of heavy steel forgings, many difficulties inherent in existing physical conditions had to be met and overcome by experience and study. Steel, as cast into a large ingot, may be perfectly homogeneous in its fluid condition at a high temperature, but during cooling and solidification, various defects may originate in the ingot and have to be guarded against in the further steps of manufacture. These defects are, principally, interior shrinkage or "piping," blow-holes or cavities, due to the evolution of gas during cooling and solidification, external or surface cracks, internal cracks, due to shrinkage strains, and segregation, which is the concentration of certain ingredients (principally carbon, phosphorus and sulphur) towards the central upper portion of the ingot during solidification.

Further serious defects may be produced by improper re-heating for forging and by unfavourable conditions during forging, such as, for example, lack of power of machinery. Lastly, as steel is a crystalline substance whose molecular and static condition is greatly influenced by temperature, the physical qualities of a forging—*i. e.*, tensile strength, elasticity and toughness (the last as shown by the elongation and contraction of area of tensile specimens), largely depend upon the maintenance of proper conditions during the operation of forg-

TAKING AN INGOT FROM A HEATING FURNACE, AT THE BETHLEHEM IRON COMPANY'S WORKS, AT SOUTH BETHLEHEM, PA., PREPARATORY TO FORGING.



END VIEW OF THE CASTING PIT AT BETHLEHEM, SHOWING THE FLUID COMPRESSION PLANT.

ing and upon subsequent heat treatment. In general, the harder the steel—*i. e.*, the more carbon and other hardening ingredients it contains, the more likely and pronounced is the occurrence in large ingots of the most serious defects above mentioned, namely, internal cracking and segregation, and the more sensitive are its physical qualities to varying conditions of forging and the effects of temperature.

By 1870 the Siemens-Martin or open-hearth process had become thoroughly established, and it was early recognised that this was well adapted to making large steel ingots to be used in making heavy forgings. Not only can such ingots be made with greater convenience and at less cost by this process than by the crucible method, but the open-hearth furnace is especially well suited to melting a soft steel, low in carbon, which is more difficult to produce in crucibles than the harder grades of steel.

As pointed out above, the difficulties and dangers inherent in making large steel forgings become less serious with the use of a soft, low-carbon steel, owing to its ductility, and, hence, open-hearth ingots, low in carbon, were at once accepted by forgemen as desirable material from which to make heavy forgings. Further, not only are the original cost and risks of manufacture lessened by the use of soft steel, but it can be machined to shape at less expense and with greater rapidity.

It is not surprising, therefore, that with the rapid development of the open-hearth process, steel, melted by it, came into general use for forgings. This accounts largely for the fact, which it is important to note, that when steel was generally adopted by the principal naval powers and by the great transportation companies for engine forgings and shafting of war-ships and large ocean liners, thus replacing wrought iron, the specifications called for mild steel, having a tensile strength, in specimens cut from the forging, of twenty-eight to thirty tons, or about 62,000 pounds per square inch, and a minimum elongation of from twenty-two to twenty-eight per cent., according to the dimensions of the specimen and the severity of the requirements. It is also worthy of note that makers who early attained the highest reputation for the quality of their open-hearth forgings made use almost invariably of a soft grade of steel.

The use of steel for marine forgings made less rapid progress in the United States than in Europe, due primarily to the small amount of ocean steamship building that had been undertaken there, and consequent lack of proper facilities for the manufacture of steel in large masses. The manufacture of wrought iron forgings had, on the other hand, been well developed, and supplied the requirements of the coast, lake and river steamships. It was not until the rebuilding of the United States navy was undertaken in 1884 that a demand was created for engine and shafting forgings of steel, and in preparing the specifications England's lead was naturally, and at that time wisely, followed by the United States Government officials, and a soft material, with comparatively low tensile strength and high elongation, was called for.

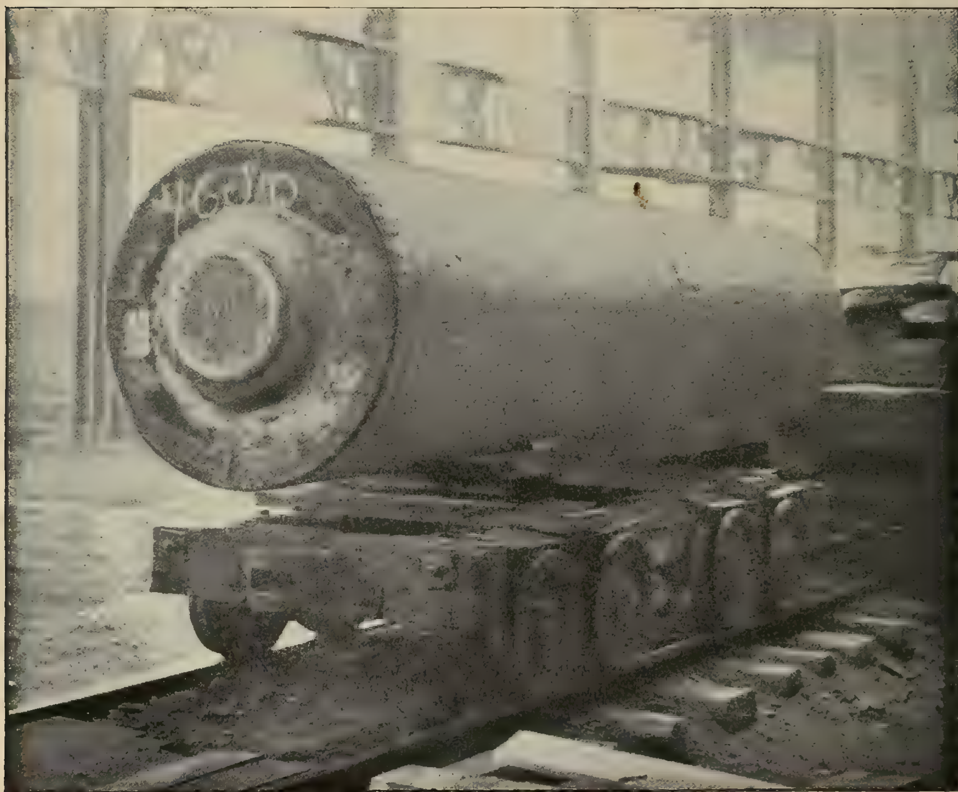
The facilities for the production of steel forgings in the United States were very limited, but the demands of the government for such material were foreseen and fully met by the establishment, in 1888 and '89, of the Whitworth fluid compression and hydraulic forging plant at the works of The Bethlehem Iron Company, at South Bethlehem, Pa.

In no department of manufacture has the system of thorough testing and the high standard of quality, maintained by the government officials, been more beneficial and instructive to the manufacturer than in the production of heavy steel forgings for ordnance and marine purposes, and much experience and knowledge has been acquired, not only in overcoming inherent difficulties of manufacture, but of the physical qualities actually possessed by large masses of steel under varying conditions. It is natural that this knowledge should have been called upon to improve the quality of steel in order to meet the

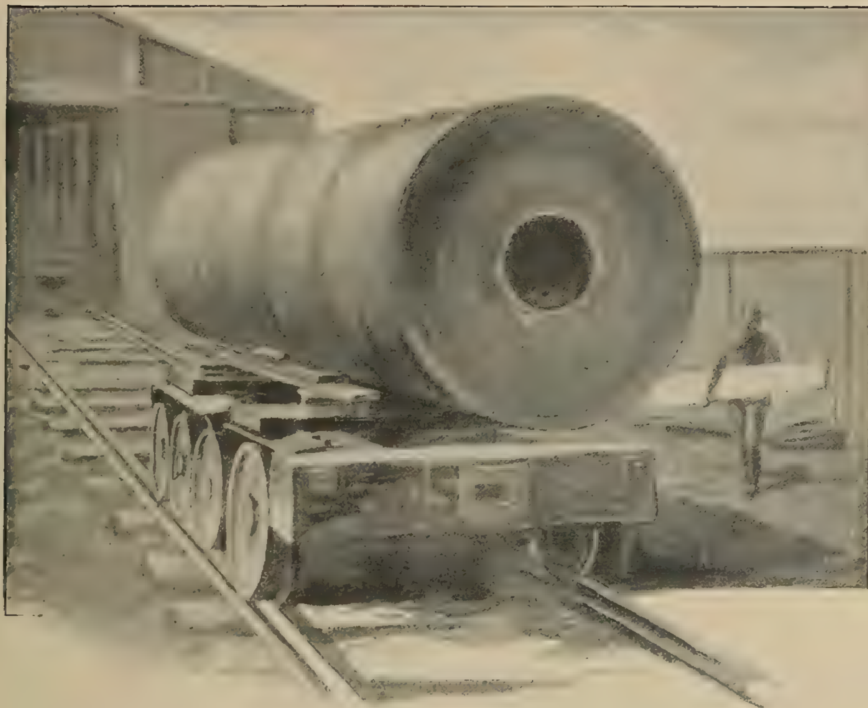
demands of modern steamship development for an increase of strength as well as decrease of weight of all moving parts, and the question has arisen whether the soft, low-carbon steel, so widely used, is the best material for the purpose.

Before attempting to answer this question, a few facts bearing upon the elastic strength of materials should be considered. By the elastic strength is meant the tensile strength up to the elastic limit. The elastic limit is the point where a stress begins to produce a permanent set or distortion of the material. Within the elastic limit the distortion, due to a stress, is proportional thereto and disappears when the latter is removed. Beyond the elastic limit the rate of elongation increases more rapidly than does the stress, and when the stress is removed, a permanent set is found to have taken place.

The tensile strength of a material corresponds with the maximum stress required to produce rupture, but in the case of ductile materials, such as wrought iron and the milder steels, a large amount of elongation takes place before the point of failure, or complete rupture, is reached. It is evident that no part of a structure should ever be strained up to, or beyond, the elastic limit of the material of which it is made, for apart from the effect of such a strain to cause rupture, a change of dimensions and line will ensue. It follows that in all structural problems the elastic limit of a material is a far more important factor than the tensile strength, and should be considered in preference thereto.



A SOLID INGOT OF FLUID COMPRESSED STEEL, BEFORE BORING.

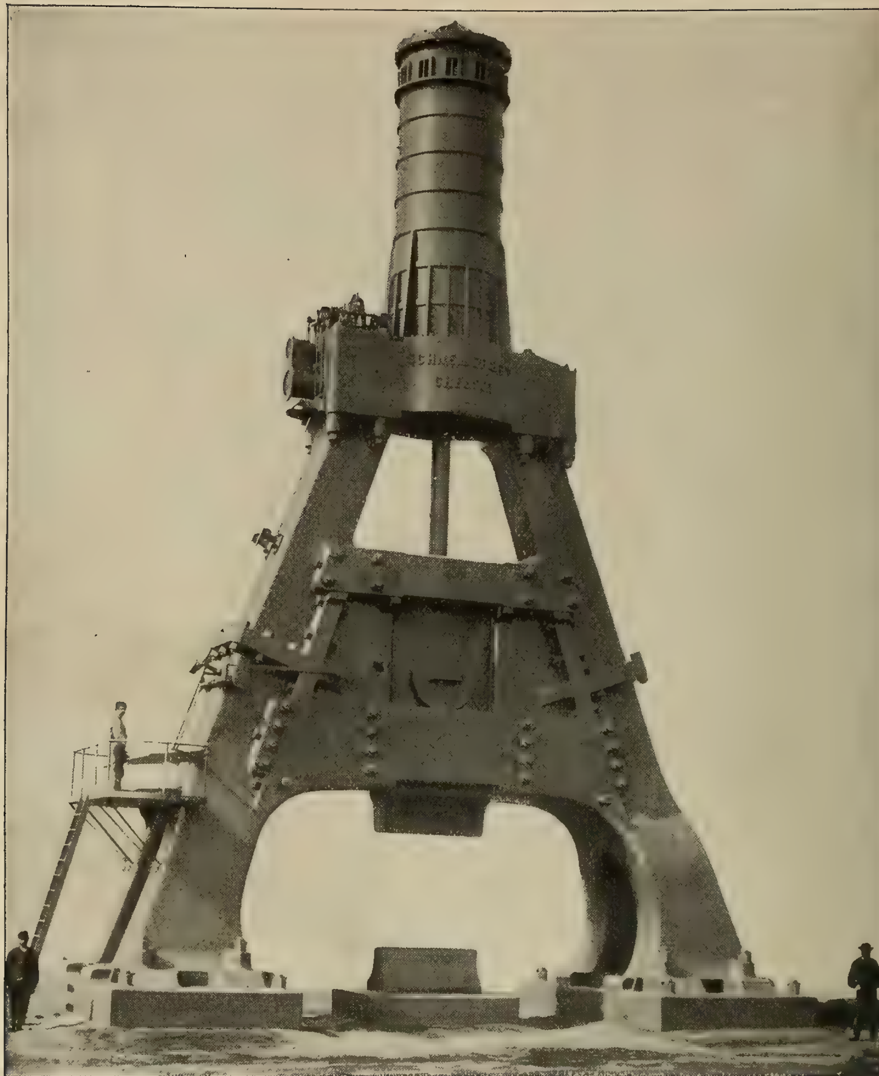


A COMPRESSED STEEL INGOT WITH A HOLE BORED THROUGH THE CENTRE, PREPARATORY TO FORGING.

The objection has been made to this proposition that the elastic limit is more difficult to determine accurately than the tensile strength and that it will vary widely with different testing machines and operators. While it is true that the elastic limit, as frequently determined by the falling of the beam of an ordinary knife-edge machine, is often far from accurate, it is also a fact that when a carefully adjusted testing machine is used and proper apparatus is employed, the elastic limit can be uniformly determined with an accuracy quite equal to that reached in ascertaining the tensile strength. It is simply a question of an intelligent application of easily acquired facilities. In this connection it should be mentioned that both in theory and practice the manufacture of the modern built-up steel cannon is based entirely upon an accurate knowledge of the elastic limit of the material used, and that the results obtained by the manufacturers of steel gun forgings in determining the elastic limit of their product, agree closely with each other and with a standard.

The great importance of the elastic limit being recognised, it follows that the most desirable material for structural purposes is one possessing the highest possible elastic limit, with a sufficient toughness, as shown by the total elongation and contraction of area at rupture, to insure against fracture from excessive strain, suddenly applied, or shock.

To determine the actual physical qualities of masses of metal of large sectional area, such as forgings, specimens should be invariably prepared by machining cold from a full-sized prolongation of the forging or from surplus metal that has not received more work in forging than the average of the working cross sections, and after the forging



THE 100-TON HAMMER AT THE WORKS OF MESSRS. SCHNEIDER & CO., AT CREUSOT, FRANCE.

has been submitted to all the heat treatment which it is to receive. The elastic limit of heavy wrought iron forgings, when determined in specimens prepared as above, is about twenty-two thousand pounds, or about ten tons to the square inch, more or less.

The elastic limit of steel varies within a wide limit, according to the hardness and strength of the metal and the treatment that it has received. In masses of steel of ordinary quality, *i. e.*, not alloyed with unusual ingredients, having a considerable area of cross-section, such as large forgings, which have received no other treatment after forging than simply annealing, the elastic limit averages somewhat less than one-halt the tensile strength, about 47 per cent. Thus the elastic limit of a steel having a tensile strength of about 60,000 pounds per square inch will be about 28,000 pounds. This ratio of elastic limit to the tensile strength can be increased by

tempering, *i. e.*, hardening by sudden cooling, with subsequent annealing, and by the introduction into the metal of a proper amount of certain unusual ingredients, notably nickel.

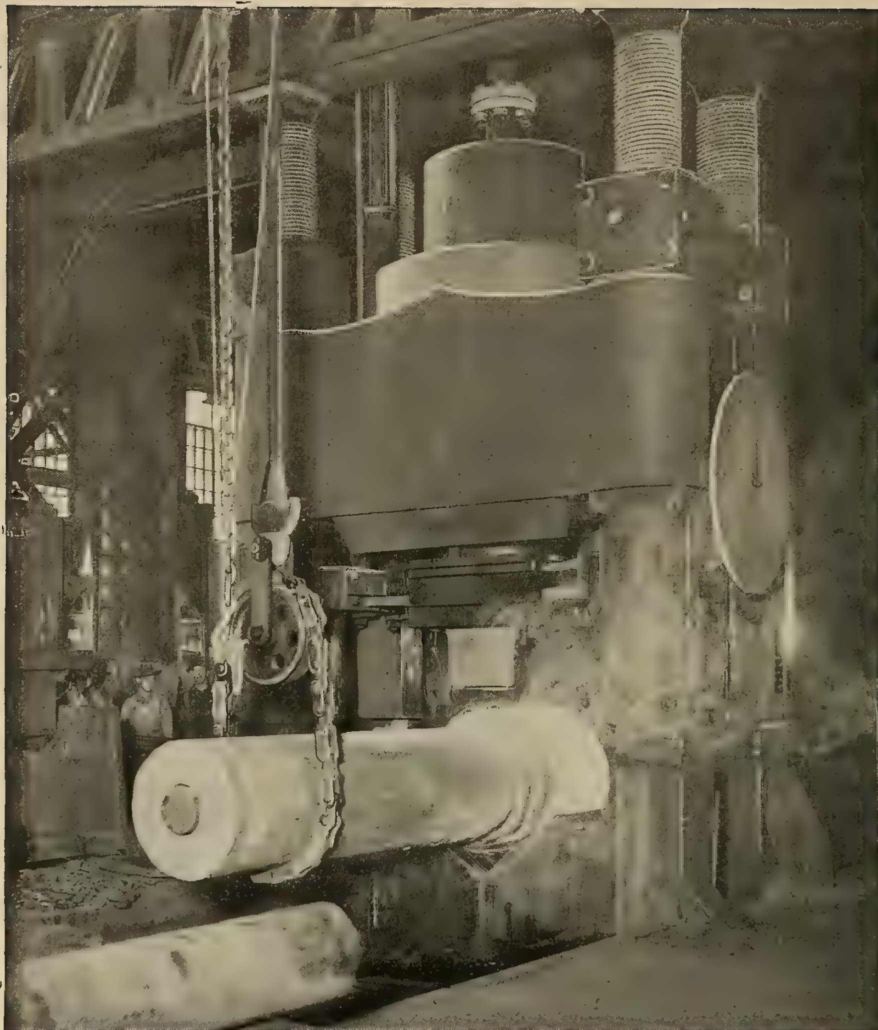
The moving parts of marine and other engines which most frequently fail by fracture are those subjected to torsional and alternating transverse and varying strains, due to revolution, such as crank pins, and crank, line and propeller shafts. Under normal conditions, with these parts running true under ordinary load, these strains may not nearly equal the elastic limit of the metal, but if from any cause the elastic limit is repeatedly approached, a "fatigue" of the metal sets in, and a parting of the outside fibres or layers begins to take place. This parting will gradually extend inward and all around the piece until fracture finally ensues. This has been called "fracture in detail" and is recognised in the fracture by a discoloured outer ring of varying width, surrounding a bright inner portion. A careful study of the occurrence of such fractures indicates that they can be most surely avoided by increasing the elastic limit of the material of which the parts are made, and thus increasing the excess or margin between the maximum repeated working stress and the elastic strength of the metal.

This fact has been fully demonstrated by a study of the cause of fracture of locomotive crank pins. When steel was first used for such pins, instead of wrought iron, a low-carbon, soft metal was generally employed, and fractures of steel pins were almost as numerous as those of wrought iron. It was found, however, that by using a considerably harder steel, fractures were very much diminished in number without increasing the diameter of the pins, and now, according to the best practice, such crank pins are made of metal having a tensile strength of from 80,000 to 90,000 pounds per square inch, and an elastic limit of about 40,000 pounds, or nearly twice that of wrought iron.

The conditions of stress in the case of marine engines cranks and shafting are approximately similar to those affecting locomotive crank pins. The primary torsional stresses are accompanied, especially in the cranks, by alternating transverse strains and the latter also occur in the line shafting and become important when, owing to wear or other causes, the bearings are not perfectly in line. Fracture usually occurs at or near the juncture of the crank pins or shafts with the webbs, or near the flanges or bearings of the shafts where the transverse stresses are most accentuated. It can, therefore, be surmised that these stresses can best be resisted, and fractures avoided as far as material is concerned, by increasing its elastic limit, or, in other words, by using a harder, stronger steel.

However, the inherent difficulties in

HOLLOW PROPELLER SHAFT OF THE AMERICAN LINE STEAMERS "ST. LOUIS" AND "ST. PAUL." LENGTH, 53 FEET 5 INCHES. OUTSIDE DIAMETER, 21 INCHES. INSIDE DIAMETER, 6 INCHES.



HOLLOW-FORGING A SHAFT UNDER A 5000-TON HYDRAULIC PRESS AT THE BETHLEHEM WORKS.

the manufacture of forgings become greater with an increase in the hardness of the steel. Of these difficulties the more important are the occurrence of internal, axial defects such as transverse cracks or pulls, either originating in the ingot by contraction, or developed during reheating and forging; and, further, the greater tendency of the harder steels to assume a form of crystalline structure when cooling, during and after forging, which diminishes their normal ductility and toughness.

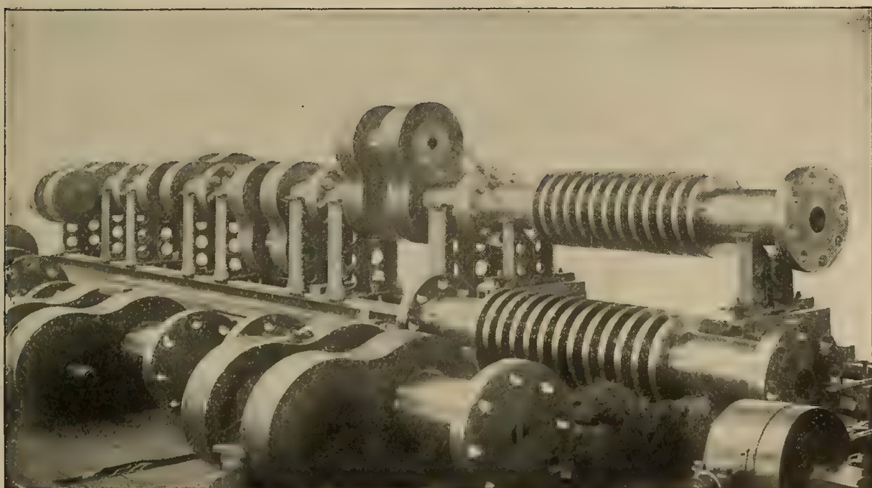
The presence of axial defects can be ascertained, and the smaller ones removed, by boring longitudinal axial holes through the forging, and good practice now demands that this shall be done with all grades of steel, not only with the object above mentioned, but also to reduce weight by removing material which adds little to the strength of the piece; for it is interesting to note that if an axial hole, having a diameter one-half that of the outside, is bored through a cylindrical mass, the resist-

ance of the mass to torsion is reduced only 6¼ per cent., while the weight is reduced by 25 per cent.

The undesirable crystalline condition above mentioned is modified and the toughness is increased by annealing in all grades of steel, but to a less degree in the harder than in the softer metals, and in order to develop the full value of the harder steels, *i. e.*, a combination of strength and toughness, as indicated by a high elastic limit, and elongation, and contraction of area, tempering is especially useful.

The method of manufacture of large cylindrical forgings which completely on a mandril, which can be best done under an hydraulic forging press.

This arrangement insures conditions especially favourable to thorough forging, owing to the fact that the thickness of the walls of the bored ingot is much less than its total sectional thickness when solid, and consequently the final forging is done at a lower and more uniform temperature than can be the case in the thicker solid mass where, at the end of forging, a cool exterior surrounds a more highly heated core which, by slow cooling, becomes coarsely crystalline and, hence, deficient in toughness. Ingots produced with fluid compression



CRANK AND THRUST SHAFTS FOR THE AMERICAN LINE STEAMERS "ST. LOUIS" AND "ST. PAUL."

avoids the danger of internal defects and reduces to a minimum the injurious crystalline condition existing in an untreated mass, is forging hollow on a mandril. This is especially applicable to line shafting and crank pins of large diameter. The first step in this process consists in boring an axial hole through the ingot before forging takes place, whereby the segregation and internal defects are completely removed; the heating of the ingot for forging is also facilitated and the danger of the occurrence of internal heat cracks is greatly reduced by the presence of the axial hole. The second step after heating is the elongation of the mass by forging are especially well adapted to boring and hollow forging, and the most perfect forgings possible are made in this manner and from such material.

As, in order to insure the best effects of tempering, the sectional thickness of a mass of steel should be reduced as much as possible, and as all cylindrical forgings should be prepared for tempering by having an axial hole throughout their length, it will be readily seen that shafts, pins, and other parts, forged hollow on a mandril, are in the requisite condition for tempering and that the favourable molecular condition attained by such hollow forging, combined with the improvement resulting from temp-

HOLLOW CRANK SHAFT FOR THE U. S BATTLESHIP "IOWA."

ering, must give the best attainable results.

If, owing to the irregular shape of forgings, oil-tempering is not desirable, or if, for other reasons, it is considered unnecessary, the use of a medium hard steel is recommended, which, after proper forging and annealing, possesses, combined with a good elongation indicating toughness, an elastic limit considerably higher than that of an ordinary mild steel of 60,000 pounds, or about twenty-seven tons tensile strength.

In order to increase the desirable qualities of steel, among which, as already pointed out, a combination of high elastic strength and ductility or toughness is of the first importance, steel makers have done much experimenting to determine the effect of varying the composition of the metal and of introducing into it various unusual elements such as chromium, nickel, tungsten, and others.

In 1889 Dr. Riley, of the Steel Company of Scotland, presented a very valuable paper to the British Iron and Steel Institute, giving the results of his experiments on introducing nickel into steel, which indicated a marked improvement in physical qualities. The first application of this improvement in quality of steel by the use of nickel was in the production of open-hearth steel armour plate by MM. Schneider & Co., at the Creusot Works, in France. The experiments of this company demonstrated that a moderate amount of nickel,—about 3¼ per cent.,—so increased the toughness of steel of a given hardness or tensile strength, as to greatly add to its resistance to cracking from the shock of projectile impact.

An examination of the physical characteristics of this metal shows it to possess valuable qualities which explain its toughness and resistance to shock. The nickel acts as a hardener, replacing a part of the carbon and, with a given tensile strength, increases somewhat the elongation, and to a greater degree the contraction of area, at the point of fracture. Its effect upon the elastic limit is, however, of the greatest importance, as it raises this quality in a marked degree relatively to the tensile strength and thus insures a combination of elastic strength and ductility, or toughness, unknown in any other metal. The presence of the nickel also renders the steel sensitive to the good effects of tempering, and the desirable qualities above mentioned are accentuated by this treatment.

It is evident, in the light of previous considerations, that this comparatively new metal, offering a marked increase, both of elastic strength and toughness, is admirably adapted to the manufacture of marine and other engine forgings and shafting, and already a number of important forgings have been manufactured and subjected to practical trial.

The following is an approximate statement of the average physical qualities that can be obtained in forgings made of the several grades of steel and varying in the mode of manufacture as above indicated, the tensile specimens being one-half inch in diameter and two inches long between marks and cut from full-sized prolongations of the forgings after treatment.

Mild Steel Annealed.

Tensile strength	63,000 lbs.
Elastic limit	30,000 "
Elongation	28 p. ct.
Contraction of area	50 "

Medium Hard Steel—Annealed.

Tensile strength	80,000 lbs.
Elastic limit	37,500 "
Elongation	23 p. ct.
Contraction of area	40 "

Medium Hard-Steel—Oil-Tempered Axial Holes, where Practicable.

Tensile strength	90,000 lbs.
Elastic limit	45,000 "
Elongation	23 p. ct.
Contraction of area	50 "

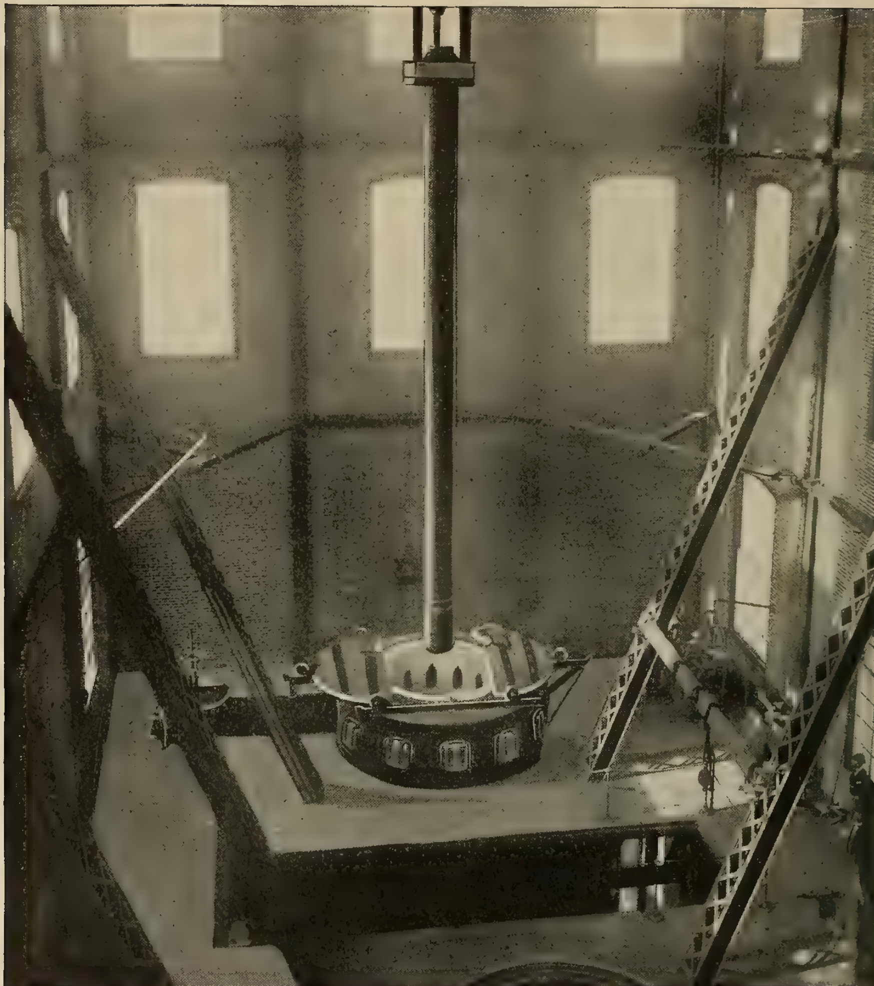
Medium Hard Nickel Steel—Annealed.

Tensile strength	85,000 lbs.
Elastic limit	45,000 "
Elongation	25 p. ct.
Contraction of area	50 "

Medium Hard Nickel Steel—Oil-Tempered. Axial Holes, where Practicable.

Tensile strength	93,000 lbs.
Elastic limit	55,000 "
Elongation	25 p. ct.
Contraction of area	60 "

In naming the above qualities in tempered material, the sectional thickness is assumed to be considerable, say three inches and over. When the thickness is reduced to say one or one and one-half inches, the elastic limit of simple



TEMPERING A SHAFT IN OIL.

steel can be raised to about 55,000 or 60,000 pounds, and of nickel steel to 65,000 or 70,000 pounds per square inch without reducing the ductility.

From the foregoing the following conclusions may be drawn:—

First.—In the present condition of the art of manufacture steel is, in all respects, a material considerably superior to wrought iron for marine engine forgings.

Second.—The physical qualities desired in steel forgings of moving parts of engines and of shafting are a high elastic strength combined with ductility or toughness.

Third.—While good reasons have existed, and may still exist, in some instances, for the use of mild steel, with a tensile strength of about 60,000 pounds (twenty-seven tons) per square inch, for marine forgings, this material has a comparatively low elastic strength and cannot be considered as the best for the purpose.

Fourth.—To obtain high elastic strength, together with ductility or toughness, a harder or higher carbon

steel should be employed, and wherever practicable this steel should be oil-tempered in order to fully develop the qualities desired. The less the sectional thickness of a piece of steel, the more its qualities are improved by tempering.

Fifth.—The introduction into steel of a moderate amount of nickel increases its elastic limit relatively to its tensile strength, and at the same time adds to its ductility, thus producing a metal especially well adapted to engine forgings. The improvement in qualities due to nickel are accentuated by tempering.

Sixth.—Whenever practicable, marine engine forgings and shafting should be made hollow. This is highly desirable in forgings of untempered steel in order to insure against, and remove, hidden axial defects and to reduce weight by dispensing with material which adds but little to the capacity of the piece to resist torsional and bending strains. When forgings are to be tempered, axial holes through cylindrical portions are necessary to avoid the dangers of internal cooling strains and cracks, and to insure the beneficial effects of tempering by rapid cooling from the interior as well as the exterior of the mass.

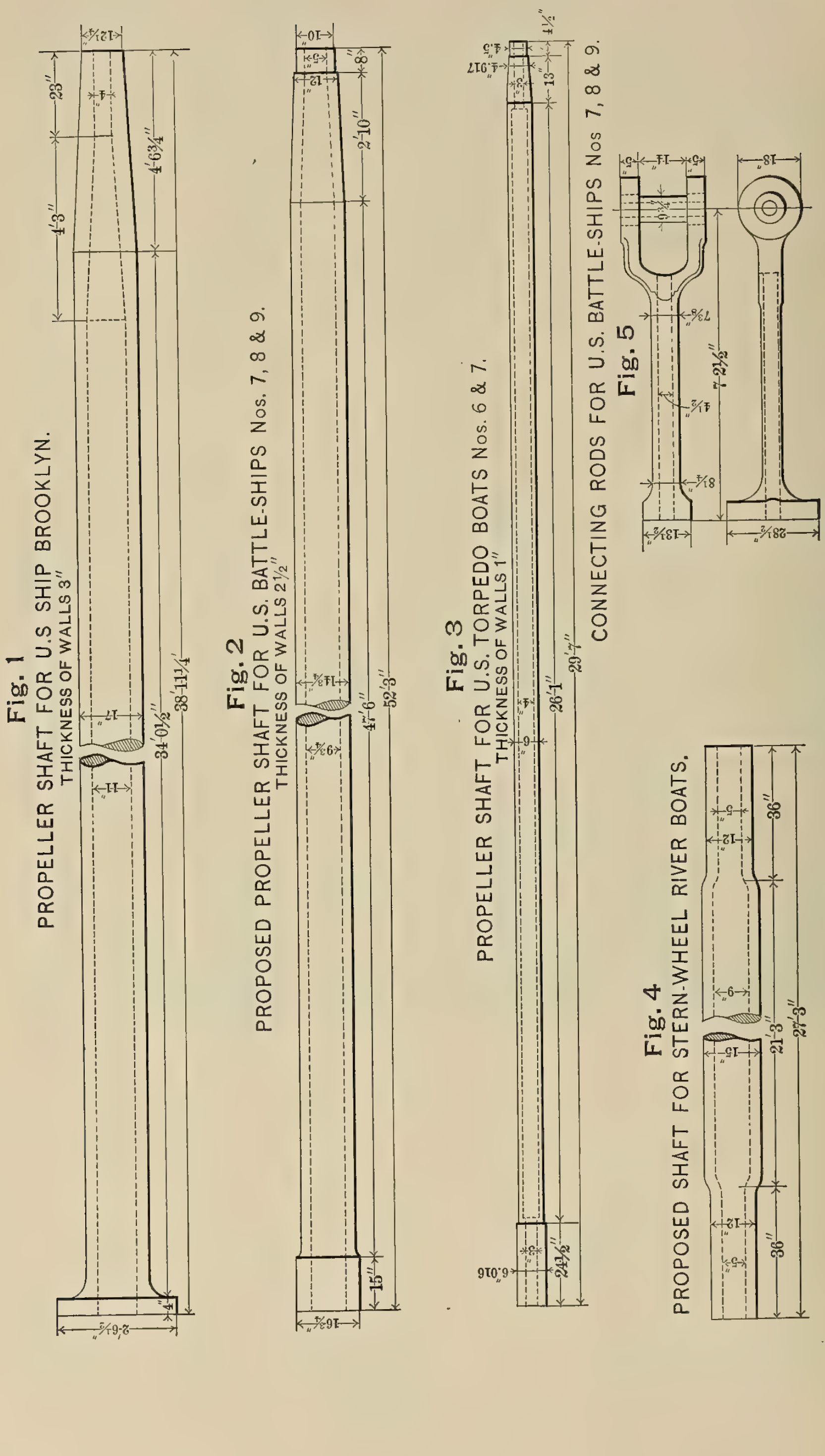
Seventh.—In utilising the higher physical qualities attainable in steel forgings, outside diameters should not, in general, be reduced, as a loss in stiffness would result; the forgings, however, should be made hollow and inside diameters be increased, thereby greatly reducing weight and obtaining the full advantage of the benefits of tempering.

Eighth.—The most desirable method of producing hollow forgings, wherever practicable, is to bore an axial hole through the ingot and forge hollow on a mandril.

A few instances of the latest application of the improved qualities attainable in steel to the design of marine engine forgings and shafting, with a view of decreasing their weight while maintaining or increasing their strength, will be of interest.

In Fig. 1 of the diagrams on the next page, is shown an outboard propeller shaft of the United States protected cruiser *Brooklyn*. These shafts were made by The Bethlehem Iron Company of fluid compressed nickel steel, hollow forged and oil-tempered. They were the first shafts introduced into the United States Navy, made of steel having a high elastic limit instead of the standard mild steel with a tensile strength of 62,000 pounds (twenty-eight tons) per square inch and about 30,000 pounds (thirteen and one-half tons) elastic limit. The specifications called for are, tensile strength 85,000 pounds (thirty-eight tons); elastic limit 50,000 pounds (twenty-two tons) with 23 per cent.

NICKEL STEEL PROPELLER SHAFT FOR THE U. S. CRUISER "BROOKLYN." HOLLOW FORGED OUTSIDE DIAMETER, 17⅛ INCHES INSIDE DIAMETER, 11 INCHES. LENGTH, 38 FEET 11⅜ INCHES. WEIGHT, 19.112 POUNDS.



11 INCHES, LENGTH, 38 FEET 11⅜ INCHES. WEIGHT, 19,112 POUNDS.

elongation in four diameters. The physical qualities shown by the official tests of these shafts was:—

	T. S.	E. L.	Elong	Cont.
Average	93,000 (41½ tons.)	59,000 (26 tons.)	26.33 p. ct.	60.24 p. ct.
Minimum	87,000 (39 tons.)	55,000 (24½ tons.)	24.00 p. ct.	57.48 p. ct.

In a paper, read by the writer before the Society of Naval Architects and Marine Engineers in 1893, the following comparison was given of the strength of these shafts, within their elastic limit, with that of solid shafts of the same sectional area made of soft, simple steel, having an elastic limit of 30,000 pounds per square inch, and also a comparison of their weights per linear unit with that of soft steel solid shafts of equal strength. The calculations were made by Professor Mansfield Merriman, of Lehigh University:—

further in the case of the line shafting for the three new battle ships which have recently been contracted for by the United States Navy Department. An outboard propeller shaft for these ships is shown in Fig. 2; its outside diameter is 14¾ inches, inside diameter 9¾ inches, thickness of walls 2½ inches. The specifications call for a tensile strength of 80,000 pounds (thirty-five and one-half tons), elastic limit of 50,000 pounds (twenty-two tons), average elongation 25 per cent. in 2x½ inch. No specimen to fall below 23 per cent.

On comparing this shaft, having an elastic limit of 50,000 pounds per square inch, with one of the same outside diameter having an axial hole 6 inches in diameter instead of 9¾ inches, and made of mild steel having an elastic limit of 30,000 pounds (thirteen and

Case 1. Comparison of Three Steel Shafts.	Propeller Shaft U. S. S. *Brooklyn.* Hollow. Outs. Diam. 17", Ins. Diam. 11", Nickel Steel. E. L. 50,000 lbs. Per sq. in.	Solid Shaft, Same (Approximate) Sectional Area. Diameter 13", Simple Steel, E. L. 30,000 lbs. Per. sq. in.	Solid Shaft of Same Strength Under Applied Loads or Horse-Powers. Diam. 18.90", Simple Steel, E. L. 30,000 lbs. Per. sq in.
Areas of sections, square inches	131.95	132.73	280.55
Weights per yard, pounds	1,346	1,354	2,861
Comparative strengths under applied loads in flexure or under applied horse-powers in torsion	307	100	307
Load, in pounds, at middle of a span of 12 feet on two supports, which strains to one-half elastic limit	276,200	89,900	276,200
Length of beam on two supports, which is strained by its own weight to one-half elastic limits	121′ 6″	77′ 6″	83′ 4″
Horse-powers transmitted at 50 revolutions per minute when strained to one-half elastic limits	15,780	5,130	15,780

From the above it will be seen that by the use of hollow shafts made of a steel having an elastic limit of 50,000 pounds (twenty-two tons) per square inch, there is a gain in strength of three to one, and a reduction in weight of more than one-half as compared with a solid steel shaft of equal weight and equal strength respectively.

In point of fact, the actual elastic strength of these shafts was represented by an elastic limit of nearly 60,000 pounds (twenty-seven tons) instead of 50,000 pounds (twenty-two tons) per square inch, and if this higher figure were introduced into the calculations, the comparison would be still more striking.

The reduction of the thickness of walls of hollow shafting has been carried still

one-half tons) per square inch, we find that the weight has been decreased 32½ per cent. and that the torsional strength within the elastic limit has been increased 38.6 per cent.

The possible reduction in the weight of shafting for torpedo boats by the use of high elastic limit steel, is exemplified in the case of the shafting made by The Bethlehem Iron Company for the Herreshoff Manufacturing Company, to be used in the United States torpedo boats Nos. 6 and 7.

The first inquiry called for solid shafts about 6 inches diameter, made of a steel to meet the requirements of the specifications, *i. e.*, 80,000 pounds (thirty-five and one-half tons) tensile strength and 26 per cent. elongation in 2x½ inch diameter. To meet these requirements

it was proposed to use nickel steel, annealed, but not tempered, of which the elastic limit would be about 50,000 pounds (22 tons) per square inch.

It was pointed out by the manufacturers that if the shafts were bored and tempered, an elastic limit of 65,000 pounds (twenty-nine tons) per square inch, with an elongation of 22 per cent. could be guaranteed, and that if the elastic limit were raised from 50,000 to 65,000 pounds, a hole 4.16 inches diameter could be bored through a shaft 6 inches outside diameter by which its weight would be reduced by one-half without reducing its torsional strength. The shafts were made of nickel steel 6 inches outside diameter, 4 inches inside diameter, closed in at both ends and were tempered (see Fig. 3). The average physical qualities shown by official specimens cut from these shafts were:—

	Tensile Strength	Elastic Limit.	Elongation Per Cent. in 2" x ½"	Contraction of Area PerCent.
lbs per sq. inch.	101,000	68,700	22.12	60.00
tons " "	45	30½		

The following table gives a comparison of strengths and weights of small shafts under varying conditions of dimensions and physical qualities:—

Comparison of Shafts for Torpedo Boats.

	Solid.	Hollow			
	6" O. S. D.	6" O. S. D., 3" I. S. D., Tempered.	6½" O. S. D., 4" I. S. D., Tempered.	6" O. S. D., 4.16" I. S. D., Tempered.	7.2684 O. S. D., 3.6342 I. S. D.
Elastic limit	50000	63000	65000	65000	30000
Area of section in sq. in	28,274	21 206	20.617	14.68	31.12
Weight per yd. in lb	288.4	216.3	210 3	149.7	317.42
Comparative strengths in torsion	100.	118.125	141.5	100.	100.
H. P. transmitted at 50 revolutions per minute when strained to one-half E. L	841.	993.5	1190	841	841

When shafts are heavily loaded between bearings, they act as revolving beams, and are usually given the necessary strength by increasing the diameter between the bearings. This principle can be carried out with great advantage with hollow shafts by increasing both the outside and inside diameters between the bearing ends.

As a practical illustration of interest, a proposed shaft for a stern wheel boat, as used on the Western rivers in the United States, and shown in Fig. 4, may be cited. This shaft was proposed as a substitute for a solid shaft 12 inches hexagon between and twelve inches diameter at bearings. Assuming that the solid hexagon shaft were made of mild steel with an elastic limit of 30,000 pounds (thirteen and one-half tons) per square inch, and that the proposed round hollow shaft were to be made of nickel steel, tempered, having an elastic limit of 55,000 pounds (twenty-four and one-half tons) per square inch, the torsional strength of the two shafts within the elastic limit would be as 1 is to 2.32, while the load at the centre that would strain the outside fibre to one-half the elastic limit would be as 1 is to 5.

Fig. 5 shows a connecting rod and crosshead pin of nickel steel, to be used in the engines of the United States battleships Nos. 7, 8 and 9, about to be built. Axial holes are bored through the stem of the rod and through the pin, reducing the weight by about 15 per cent.

The crank shafts for the above named ships are to be made of standard mild steel with an elastic limit of about 30,000 pounds per square inch. It would appear, however, that annealed nickel steel, having an elastic limit of say 45,000 pounds per square inch, would be an excellent material for these cranks.

Marine engine forgings as above described, possessing the high physical qualities indicated are, of course, considerably more expensive than forgings made of wrought iron or of ordinary mild steel, but this increase in cost is not very great when compared with the total cost of the ship.

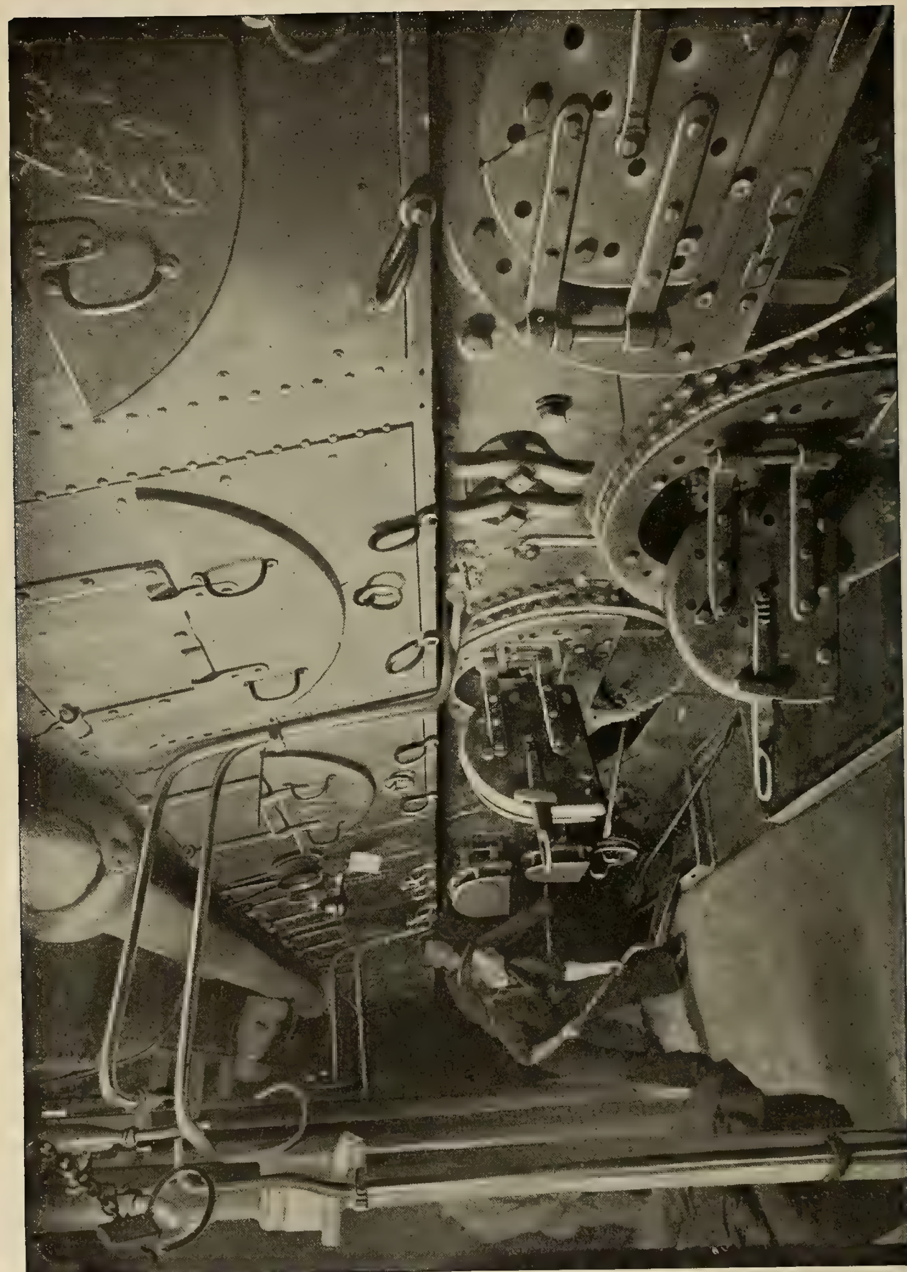
THE COALING OF STEAMSHIPS.

By S. Howard-Smith.

A GROUP OF MAN OF WAR'S STOKERS.

HEAVY investments in plants and machinery and the development of many notable inventions, have made the coaling of vessels for cargo a fairly economical and rapid process, though the waste resulting from breakage has been reduced but little. On the Atlantic coast, in the United States, colliers are generally loaded from trestled piers. Coal trains of bottom-dumping cars are run up on the trestling and their contents are discharged, by gravity, over screens and through chutes, into the holds of the vessels, where the necessary trimming is done by gangs of labourers. Such piers are a familiar sight at the tidewater terminals of all coal carrying railroads.

Numerous attempts have been made to reduce breakage by checking the fall of the coal from these elevated cars. One of the most effective devices, judging from its continued and extended use, is the Henkel chute, which may be described as a long vertical box of rectangular section, secured to the face of the trestle, and connected at its upper end with the hopper into which coal falls from the car. The seaward side of this box is composed of a series of pivoted doors, each of which, when in



THE FIRE ROOM ON BOARD THE UNITED STATES BATTLESHIP "MASSACHUSETTS."

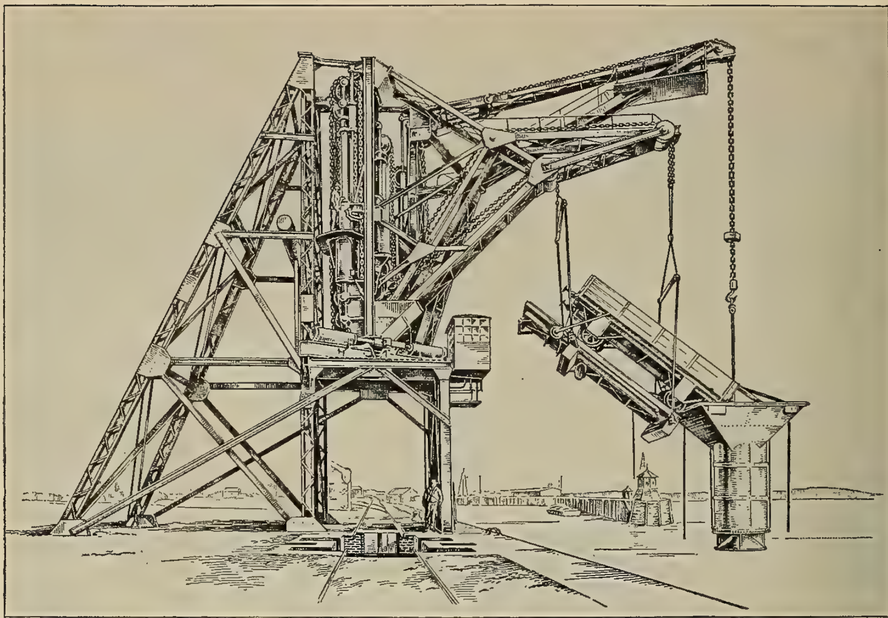
a horizontal position, forms a false bottom for the box or trunk. A chute, controlled by suitable gearing, is set to lead the coal from the open door to the vessel hatch at the least angle of depression consistent with steady flow. Delivery is thus made with minimum fall.

At ports to which coal is brought in solid bottom cars, an adaptation of the mine car, or "larry" tipple, has been employed with satisfactory results. At one of the American ports on the great lakes the car is run upon a cantilever girder and clamped. The girder is then tipped and the car raised as on a see-saw, till the coal runs out over the end into the vessel waiting to receive it. At another place the car is run into a curved steel frame-work, which is then rolled up an incline till the contents of the car are discharged. A coal handling capacity of 3000 to 4000 tons per day is claimed for these devices and they appear to meet the requirements well, except as to breakage.

Another method of accomplishing the same result is employed at Bremen, Germany. As shown in the sketch on this page, a large hydraulic crane is permanently erected over the car track, which is parallel with the face of the quay or sea wall. The car to be unloaded is run on and secured to a platform, which forms part of this track. The crane then picks up both platform and car, swings them into position over a suspended hopper, and tilts them till the contents of the car are discharged through the hopper into the hold of the loading ship. This apparatus appears to be needlessly expensive, and the direct lift of the load does not compare favourably, from a mechanical point of view, with the use of the inclined plane.

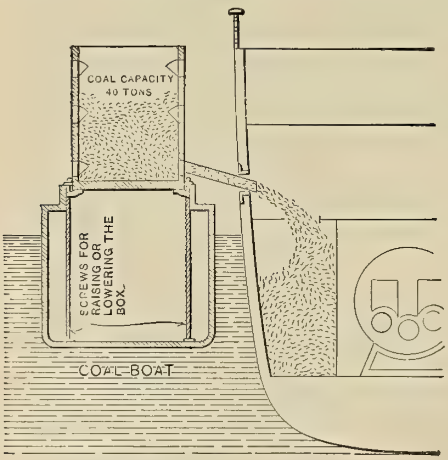
THE HENKEL ADJUSTABLE COAL CHUTES ON THE PIERS OF THE PHILADELPHIA & READING R. R. CO. AT PHILADELPHIA.

A very different problem is presented in the coaling of steamships for fuel, or



A GERMAN COAL CAR DUMPING OUTFIT USED AT BREMEN DOCKS.

"bunkering," and the methods employed in the principal ports of the world do not suggest that it has had as intelligent consideration as its importance would seem to demand; yet it is true that much inventive ability has



A PROPOSED SELF-DISCHARGING COAL BARGE.

been applied and very considerable investments have been made in the effort to lessen the time and expense of bunkering ships, with results that lend emphasis to the inquiry why this work is done to-day in almost as crude and expensive a way as when sail power was first superseded by steam.

The conditions require a double handling of the coal, as a steamship must be bunkered while discharging and taking on cargo, and must, therefore, be supplied by barges loaded from stocks and brought to the side of the ship. Bituminous coal only is used, which will not run freely or trim itself, and as it is not sized, but contains lumps two feet in diameter, dust and all intermediate sizes, it is much more difficult to unload and stow away than anthracite would be.

All the ships of the transatlantic lines are coaled in New York, for example, by practically the same crude method. Barges of about 350 tons capacity are brought alongside of the ship, booms are rigged and, by tackle, controlled by a donkey engine, steel buckets are lowered to the barge, filled by four men with shovels, and hoisted to a projecting platform, where two men dump the bucket and shovel the coal into the port

hole. It is then taken by other men and stowed away in the ship's bunkers. Five and a half of these bucket loads equal a ton, and tally by count of the buckets is the only record to show how much coal the steamer has taken aboard.

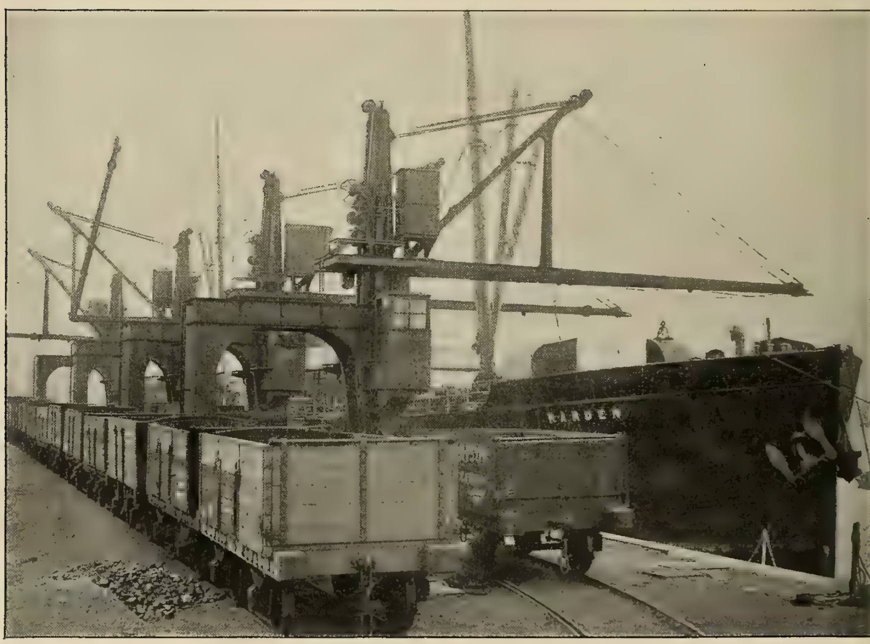
In coaling the steamship *St. Paul*, of the American line, forty-eight men are employed inside of the ship. The average amount of coal bunkered is 3000 tons; the time required to unload and stow is about forty hours, and the total average cost of the work is $1000 (or about £200). These figures, varying only with the coal consumption of the ship, will apply to the vessels of other transatlantic lines.

Effort to reduce this expense has been productive of many ingenious mechanical devices, among which may be mentioned a barge, completely filled with square compartments or boxes, holding about 40 tons each. These compartments work in guides and are adapted to be separately raised by mechanical means above the level of the ship's port. Through a chute, connecting with a door in the side of the compartment, the coal is then dis-

THE ORDINARY WAY OF COALING A STEAMER.

COALING A STEAMER IN THE WEST INDIES.

SELF-DISCHARGING BARGE COALING A STEAMER IN MOBILE BAY, ALA., U. S. A.

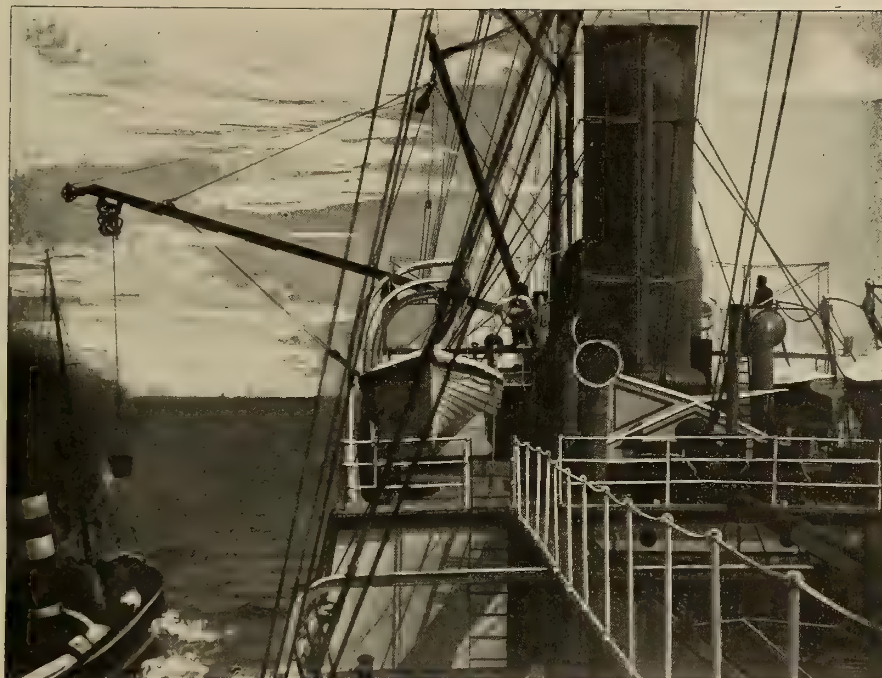


COAL HANDLING MACHINERY OF MESSRS. WM. CORRY & SONS, AT THE TILBURY DOCKS, LONDON.

charged into the ship. This scheme was not carried beyond the experimental stage, though it is reported to have shown a saving of both time and expense on trial.

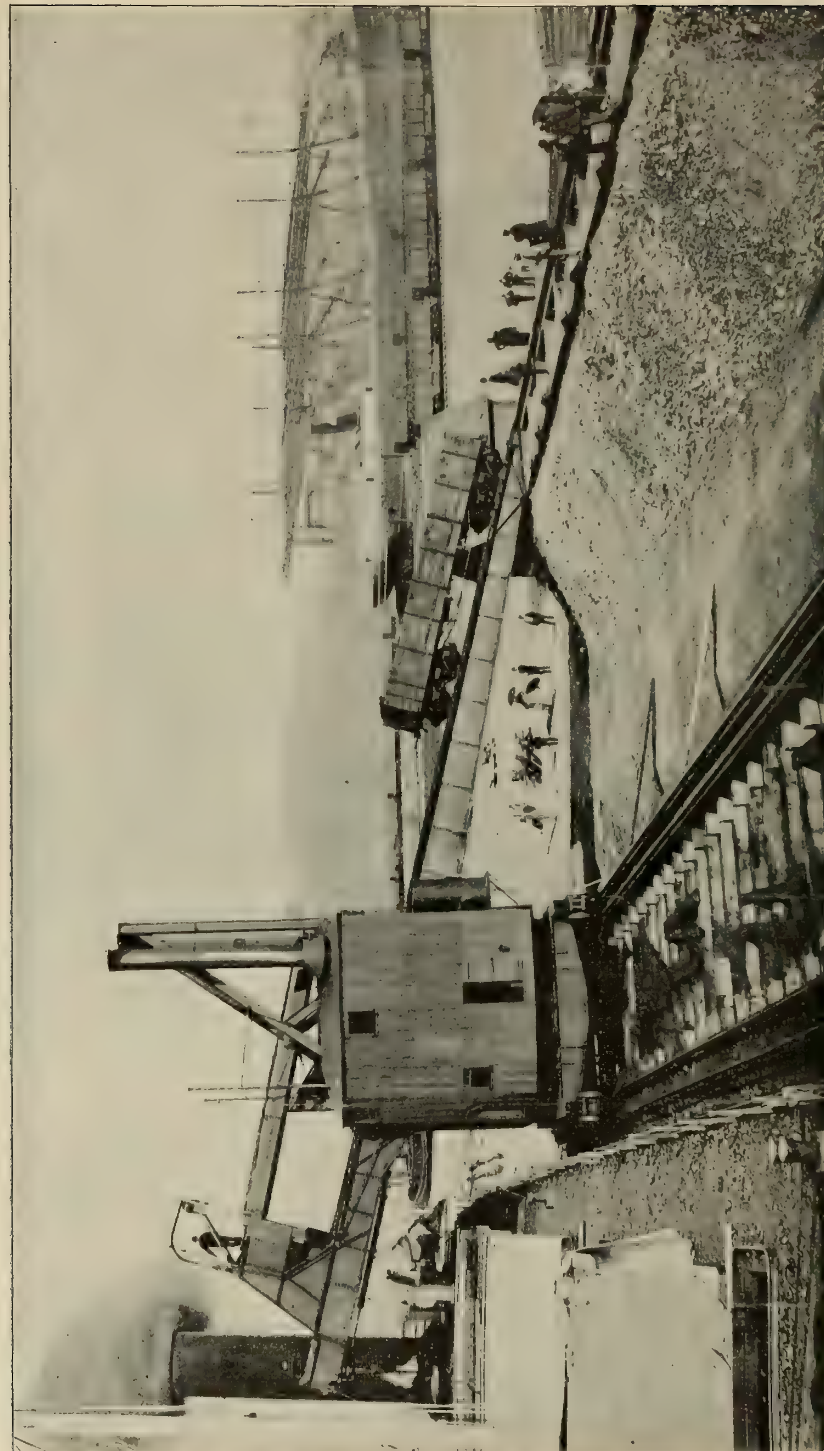
The same general idea has been worked out a little differently on the great American lakes. At Buffalo, Erie and Cleveland may be seen decked barges, each equipped with a turntable crane, mounted on trucks and so adapted to move fore and aft as required. On the deck of the barge five-ton boxes or tubs of coal are set close together, and when the barge is laid alongside the steamer to be coaled, these boxes are raised, swung over and dumped aboard of her by the crane. No great saving of labour is apparent, but the work is quite rapidly done and the service of these crane barges is a distinct advance over methods in previous use.

Superior to any of these devices is the self-discharging barge, which has only recently,—and almost simultaneously in England and in America,—been made an operative success. One of these barges is in regular use in Mobile Bay, in the United States, and the other operates on the Thames, in England. In both the coal with which the barge is filled, is drawn out and carried up an incline to a height sufficient to permit delivery through chutes into the ports of a ship, by endless carriers or conveyers. One engineer and two helpers, to control the gates and spouts, have been found a sufficient force to operate one of these barges, and from 80 to 100 tons an hour have been transferred to the receiving ship.



COALING A SHIP AT SEA BY MEANS OF A TEMPERLEY TRANSPORTER, MADE BY THE TEMPERLEY TRANSPORTER CO., LONDON. THE LIDGERWOOD MANUFACTURING CO., NEW YORK, BUILDERS AND SOLE LICENSEES IN THE UNITED STATES.

A glance over the record of accomplishment in this field revives the inquiry why none of these modern methods are in general use. The answer is given in the statement by a representative of one of the transatlantic lines:—" We have had many offers to deliver coal to our



THE MC'MYLER "SEE-SAW" CAR DUMPING MACHINE AT THE COAL AND IRON ORE DOCKS OF MESSRS. PICKANDS, MATHER & CO., AT ASHTABULA, OHIO, U. S. A.

H. M. S. "ROYAL SOVEREIGN" BEING COALED BY A STEAM COLLIER FITTED WITH TWO TEMPERLEY TRANSPORTERS.

steamers at the rate of anywhere from 50 to 500 tons per hour, but what is the use when we cannot take care of it inside any faster than we do now." In a modern ship, fuel must be stored wherever room can be found that is not required or available for other purposes. Coal cannot be received on board faster than it can be stored away in the bunkers, which, in the case of a modern liner, is at the rate of about one and one-half tons per man per hour.

The time and money to be saved make the subject well worthy of co-operative study by mechanical engineers and ship designers. The former have not lagged. The latter have perhaps the more difficult task.

More primitive methods prevail in ports of less importance than those at either end of the Atlantic lines. In the West Indies coaling is almost exclusively done by negro women who pour in a ceaseless stream over the gang planks, each carrying about 100 pounds of coal in a basket poised on her head.

In Mediterranean ports the work is done by men, instead of women, but, for the most part, with the same primitive instruments,—shovel and basket. Even with these the speed at which the coaling is done is limited by the vessel's facilities for receiving and storing. Like methods obtain at other intermediate ports, and the conclusion is inevitable that increase of facilities on board ship must precede further developments in coaling machinery.

In a paper read before the American Society of Naval Architects and Marine

Engineers, in 1893, Lieutenant Albert P. Niblach voiced the general feeling of naval constructors and officers in a criticism of existing arrangements of bunkers on warships, and emphasised the importance of such changes as would quicken the work of coaling. A very ingenious plan for larger and more accessible bunkers was incorporated in his paper, but the discussion which followed appeared to demonstrate its impracticability, and leaves the subject little advanced. It was shown that even on the newest and largest ships in the United States Navy, for example, the demand for space was never satisfied.

So closely is it figured out and apportioned, that on one of these ships the room finally assigned for the engineers' work shop measured 5 feet by 4 feet. Much of the ship's stores and munitions must obviously be given space where they are not subjected to excessive heat, and coal must, therefore, go where other things cannot, and where its weight will tend to give stability to the ship, rather than make her top-heavy. It seems probable that an improved condition will either first be worked out in the mercantile marine, where complications are fewer, or else that the problem will await a solution until actual employment of some of the navies of the greater powers in war, points out clearly the relative importance of what are now conflicting views and interests and compels internal re-arrangement.

Even a brief discussion of this subject would be incomplete without mention of the most interesting experiments which have been made in the coaling of ships at sea, and the apparatus with which these experiments were successfully conducted, known as the Temperley transporter. This device consists of a locking carriage adapted to travel along a runway attached to a boom or other convenient and usually portable support. Through this carriage is passed a single wire rope, one end of which is attached to an operating winch, conveniently located, and the other to the load to be transferred. The locking carriage remains in a fixed position relative to the runway while the load is being lifted, but when the load has been run up to the carriage, the latter, under the continuing pull of the rope, travels along the supporting boom to the required point, where it again locks itself in position, while the paying out of the rope lowers the load.

This apparatus has been employed, with various modifications, for loading and unloading vessels and stacking and storing bales, bags, barrels and other packages, but its interest in this article is confined to the service it has performed in transferring coal from colliers to men-of-war. It was first employed, and, we are informed, with marked success, during the naval manœuvres of the British squadron in 1893, when from two steam colliers, in Torbay, each equipped with two of the Temperly transporters, coal was transferred to twelve or more of the ships engaged in the manœuvres. The operation of coaling was carried on both day and night, sometimes during gales of wind and in rough water.

In 1895 the French armour-clad *Richelieu*, with the collier *Antilles*, under steam abreast of her, took in, while steaming at 6½ knots per hour, 100 tons of coal in three hours. While the transfer was being made, the vessels were kept apart by their helms and prevented from separating by cables.

The success of these coaling operations, which were at the time regarded largely as experiments, is of vast importance to the steam navies of the great powers, as a modern war ship is quite as dependent for efficiency on coal supply as on ammunition. The method of transfer is quite clearly shown in the accompanying illustrations, one of which shows the coaling of H. M. S. *Royal Sovereign* during the manœuvres above referred to, and the other, the taking in of coal from a collier by a vessel having a Temperley transporter as a part of her equipment.

SUBMARINE NAVIGATION.

By John P. Holland.

NO matter how successful the experimental submarine boat now under construction for the United States Government may prove to be, there is no one familiar with the history of radical changes in war ships that expects this vessel to revolutionise anything, either in design or tactics, that agrees with the present high standard exemplified in modern navies. The introduction of a new type to meet new conditions need not destroy anything else that is useful in other conditions.

Torpedo defenses are new and there is nothing in existence specially designed to encounter them. Nor can there be any objection to virtually extending the field they cover to the limits of the submarine boat's radius of action. A few cast iron guns in earthworks could formerly hold the most powerful fleet at bay, but the ships and shore defenses required to repel an attack from the sea in these days cannot be provided by small or poor maritime countries; and even when the means of doing so are available, many years must be spent in their construction. In the meantime, the weak and the unprepared are at the mercy of their more powerful foes.

This is the submarine boat's opportunity; yet no other device of proved worth has waited so long for adoption. It has now waited for over a century, and the present boat will be fortunate if she escape the fate that awaited Ericsson's famous *Monitor* had she failed to meet the *Merrimac* at Hampton Roads. The successful result of that encounter alone saved her from being classed as the most conspicuous failure of modern naval construction.

The Dutch refused to encourage their countryman Van Drebbel, who was compelled to court the patronage of his country's late enemies to help him build the first submarine boat that carried passengers under water and returned to the surface without accident.

Bushnell's remarkably complete vessel, by far the most perfect and effective submarine boat built before 1881, remained unappreciated in America, although his American turtles might have prevented the capture of Washington and rendered America invulnerable to England in 1812 had they been in hands accustomed to their management.

Napoleon I. set no value on Fulton's submarine boat, even though he saw its power demonstrated at Brest in 1801. He had little regard for ships or naval power, preferring to place his confidence in trained soldiers, big parks of artillery, and his own commanding genius.

The British Board of Admiralty gave Fulton no encouragement, but rather sought to prevent him from developing a method of naval warfare that, in the words of Pitt, Earl of Chatham, "would cause the trident to pass from the hands of those who hold it," and who continue to hold it. Pitt was a man of singular ability, clear-sighted, and far in advance of his time. He was easily convinced of the possibilities of torpedo attack, and he clearly foresaw that the adoption of Fulton's device by his country's enemies would be a death blow to England's power on the sea. He therefore discouraged torpedoes and submarine methods of warfare, and so complete

A SUCCESSFUL SUBMARINE ATTACK.

was his success that those weapons were almost unheard of during the following half century.

The sinking of the United States warship *Housatonic* by a Confederate submarine boat in Charleston harbour in 1864, again directed attention to its possibilities, but although many attempts were made, several of them under the patronage of European governments, none proved to be practicable. The development of vessels of this type was hindered by the secrecy maintained by every one who had any knowledge of their design. Governments guarded the particulars of their experiments in order to preserve to themselves the advantage conferred by a successful submarine boat, and the results of individual efforts were just as carefully hidden to prevent the competition of other inventors.

As each designer was thus compelled to face the problem without the knowledge of what had been accomplished by his predecessors, he had to discover for himself the main requirements of a submarine vessel, and to foresee and provide against difficulties.

The writer's first attempt, made in 1877, was no exception to this rule. He trusted to direct vision under water to guide his movements, and the difficutly of steering a straight course was not even suspected.

The result was, of course, failure. Bushnell's vessel, built just one hundred years before, was more nearly correct in principle, and in the hands of a careful, courageous man, thoroughly familiar with its management, it would have proved more formidable than even Bushnell himself expected.

The ideal submarine boat, even when the writer's first experiments were made, was a vessel that could approach a ship on the surface of the water until it came near enough to run some risk of detection, and then pass silently beneath the surface. When directly under the ship, a torpedo was either to be fastened to a vulnerable spot and exploded after the submarine boat had moved away to a safe distance, or it was to be towed underneath and exploded on contact with the bottom of the vessel.

Against the old style sailing ships and old methods of conducting offensive operations, a vessel like Bushnell's, slightly improved, would have been fairly effective in preventing a bombardment or in breaking a close blockade;

but the revolution wrought in naval design and tactics by the substitution ot steam for sail power, and by the introduction of rapid-fire and high-power guns, armour, high-speed torpedo boats and automobile torpedoes, must produce a corresponding change in the design of the ideal submarine boat, and render the solution of the problem far more difficult.

Ships will no longer anchor opposite a fort or city while bombarding them. Neither will they try to force the passage of a channel or make any direct attack during darkness, lest they fall victims to stealthy and rapid torpedo boats. Blockades will be maintained at a safe distance from the shore, and the ships will never anchor, except in cases in which there is reasonable security against the attack of torpedo boats.

In order that a submarine boat may be effective under these new conditions, we shall find that it must be changed almost beyond recognition from the original ideal.

To begin with, it must be perfectly water tight and strong enough to resist the collapsing pressure due to the depth at which it operates.

Sufficient air must be provided to afford an unstinted supply for the crew while they are under water. As the free air contained inside the boat would soon become vitiated, a large quantity must be carried under pressure in reservoirs, and permitted to escape slowly into the empty spaces in the vessel to replace the vitiated air that must be removed; or else the free air of the interior must be purified and reoxygenated. Methods of purifying the air have been employed in some submarine vessels. The writer found two objections to their use; first, they require careful management to prevent over oxygenating the air and producing exhilaration of the crew; and second, they add complication to a machine, one of whose cardinal principles must be simplicity.

Experience has shown that at least 8 per cent. of the volume of the boat must be over water when it is floating on the surface, in order to avoid the risk ot foundering while the hatches are opened to permit entrance and egress of the crew. This 8 per cent. buoyancy must be reduced before the boat can sink beneath the surface, but only for special purposes can all the buoyancy be neutralised. This may be done either by admitting water equal in volume to the emerged body of the vessel while it is afloat, or by pulling or forcing it under water.

The conditions essential to stability in a submarine boat differ from those obtaining in vessels designed to operate on the surface of the water. The surface vessel's centre of gravity is ordinarily above its centre of buoyancy; yet the equilibrium is stable, because, if the vessel is inclined to either side, the centre of buoyancy of the vessel, that is, the geometrical centre of volume of the water which it displaces, and which is the fulcrum around which it revolves, moves towards that side; and owing to the shape of the transverse section above the water's surface, the vessel cannot be so inclined without raising the centre of gravity through a distance corresponding to the inclination. Raising the centre of gravity is equivalent to raising the vessel herself through the same distance. The force tending to raise the centre of gravity is therefore resisted by the weight of the ship, and the distance through which the centre of gravity is raised, at each degree of inclination, multiplied by the weight of the ship, is the measure of her stability.

In a submarine vessel the case is quite otherwise. The centre of gravity must always be placed under the centre of buoyancy. Should it happen that, through defective design, it is not so placed, it will undoubtedly find that position when the vessel is submerged, and upset the boat, as well as the calculations of the naval architect.

Imperfect design in another particular has caused the failure of more submarine boat projects than all others combined, and that is instability, due, mainly, to a movable centre of gravity. Suppose a vessel is completely submerged and moving forward. If the centre of gravity be moved forward in the vessel at the same time, she will im-

mediately incline downward ahead and run to a greater depth, possibly deep enough to cause the collapse of the boat, unless the inclination is quickly corrected. This instability in the longitudinal direction is caused by a very low metacentric height, combined with a movable centre of gravity.

The low metacentric height is generally due to the small proportion of depth to length of the submarine vessel. The movable centre of gravity is generally owing to empty spaces left in the water ballast tanks to provide additional space to be filled with water, in case the specific weight of the vessel and its contents became lighter from any cause, such as combustion of fuel, or the expenditure of torpedoes or stores. When the vessel inclined a little from the horizontal, the water in the ballast tanks moved to their lower ends, causing a corresponding movement of the centre of gravity. This trouble reached such proportions in some cases as to cause the vessels to stand nearly on end and become unmanageable. A submarine boat should, therefore, have a fixed centre of gravity while submerged, and its water ballast should completely fill the tanks designed to hold it, so as to prevent the possibility of its movement The fuel expended should be compensated for as it is consumed, and the torpedoes discharged should be quickly replaced by an equal weight of water taken on board at the same distance from the centre of buoyancy. Both compensations must be automatic.

Except in a few of the most modern submarine boats, the intention of their designers was that the vessel should be steered by sight while under water. The employment of a powerful search light placed near the stem of the boat was also proposed to aid in finding the vessel to be attacked. The writer was of the opinion that steering by sight while submerged was quite practicable, and that it would be a simple matter to find the most vulnerable point in the bottom of a ship to which to attach the torpedo that was to blow her to pieces; but a few submerged runs convinced him that some other guide than vision under water must be found to direct the boat's movements.

There are very few important harbours in which the water is clear enough to see through for any considerable distance; and leaving aside the difficulties caused by refraction, turbid water alone is quite enough to prevent steering by sight. Those who have had no experience in submarine work will be inclined to think that operations at very moderate depths, say four to ten feet beneath the surface, would be aided by strong sunlight on a clear day. But a few experiments showed the writer that such is not the case. Water that appears fairly clear at a moderate depth on a cloudy day, assumes the appearance of a dense fog when the sun shines on it. Every small particle of solid matter suspended in the water reflects the light and effectually hinders vision. The swells or ripples passing on the water's surface have, in certain circumstances, the effect of movable prisms, sending flashes down through the water that help hinder distinct vision at even short distances.

This experience throws some doubt on the accounts of long submerged runs said to have been made by some inventors, and shows that the direction and length of the submerged run would have to be determined while the boat was on the surface of the water; and that at the end of that predetermined run the boat should come to, or near, the surface to have its course corrected by direct observation, or by the aid of a *camera lucida* in a tube projecting above the surface. Some modern submarine boats bring their turrets to the surface for a short time to enable the pilot to lay his course. When a *camera lucida* is used to assist in determining the vessel's direction, it must be withdrawn immediately so that the enemy may not be able to locate and destroy the vessel. The writer found the former method to be the preferable one.

Experience with submarine boats had been so very limited up to 1881 that more difficulty in steering a straight course by compass while submerged than while moving on the surface was

scarcely expected. The writer had no suspicion that his boat could not be steered perfectly until he tried it after making about half a dozen preliminary dives to adjust the automatic apparatus. Having become doubtful of the reliability of the compass, he had it carefully compensated, and then made a trial submerged run in New York harbour, heading the vessel towards a point which he knew was about twelve minutes' run distant.

The boat dived at an inclination of about 15 degrees; and it was noticed that when she again reached a horizontal position the compass needle swung around a complete circle, and vibrated a good deal before coming to rest. The boat was then discovered to be about 90 degrees off her course. It was steered again in the proper direction, and then inclined upward at a sharp angle to find whether the action of the compass would be as erratic while rising as while running downward. One end of the needle dipped to the bottom of the cup when beginning the ascent, and remained there during the rise. When the boat approached a horizontal position, a few feet below the surface, the needle swung around as violently as it had done during the boat's descent, and then came to rest again at a point that indicated the boat to be far off the true course.

As it appeared quite clear that the run was not made in the direction intended, and that about one mile must have been covered from the start, ten minutes having already passed, the boat was brought to the surface of the water just in time to prevent her from running on rocks that lay about twenty yards straight ahead, and sixty yards down from the starting point.

The boat had been started to run over one mile up stream, and the mile-run ended sixty yards down stream with the boat heading exactly opposite to her original direction. This erratic action of the compass was discovered to be due to heeling, or inclining from the horizontal position, and that it could not be corrected in that boat on account of the near proximity to the compass needle of considerable masses of iron that were liable to have their position changed while the vessel was submerged.

But to continue with the requirements of the modern submarine boat,—it must be propelled by engines of considerable power while moving on the surface as well as while submerged. Manual power is no longer sufficient. It is not essential that the boat have speed comparable to a battle ship, or a surface torpedo boat, because the speed of ships while in action, or while maintaining a blockade, will be moderate; and there is no good reason for requiring that the submarine boat should be capable of running much faster than the vessels it is to attack, especially if the increased speed could be gained only by sacrificing efficiency in other important particulars.

The boat should also have considerable power of endurance, so that it may be able to travel long distances. It must, further, be an independent unit, capable of renewing its own power for submerged work; otherwise its field of usefulness will be very limited.

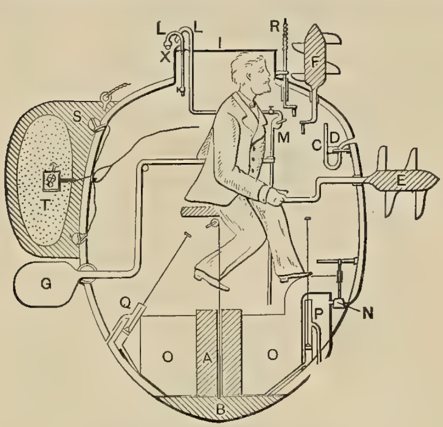
It must be able to dive rapidly so as to get safe water cover against the attacks of torpedo boats or rapid fire guns.

It must be able to manœuvre quickly, coming to the surface to lay or correct its course, and disappearing, like a porpoise, and quite as rapidly, if possible. It must also possess a suitable and effective armament, be small enough to operate in the shallow water encountered in most harbours, without becoming visible, and able to deliver its attack from a distance great enough to avoid risk of collision with the ship attacked.

The pilot must have an all-around view of the horizon when his vessel comes to the surface of the water for observation. At the same time the hull must be protected against hostile shot by water cover at least three feet in depth. The risk of injury from the enemy's fire while aiming the torpedo at the surface of the water will be thus practically eliminated.

All the submarine boat failures since Van Drebbel's time were due to the neglect of the various conditions just

outlined. Some of the boats were more or less successful, but only in the same proportion in which they complied with the stated requirements. Bushnell's boat alone embodied all the essential conditions required at the time of its construction. It was so nearly complete that the substitution of a motor for manual power, more certainty of direction while submerged, and a few other less



A SECTION OF BUSHNELL'S BOAT.

important modifications, would have rendered it quite formidable even under present conditions, and far superior to most modern designs.

The following account of that boat, communicated by Bushnell himself, in a letter, of October, 1787, to Thomas Jefferson, is worth reprinting.—

"The external shape of the submarine vessel bore some resemblance to two upper tortoise shells of equal size, joined together, the flue *H*, *I*, of entrance into the vessel being represented by the openings made by the swells of the shells at the head of the animal. The inside was capable of containing the operator and air sufficient to support him thirty minutes without receiving fresh air. At the bottom, opposite the entrance, was fixed a quantity of lead, *O*, for ballast; at one edge, which was directly before the operator, who sat upright, was an oar, *E*, for rowing forward or backward; at the other edge was a rudder, *G*, for steering.

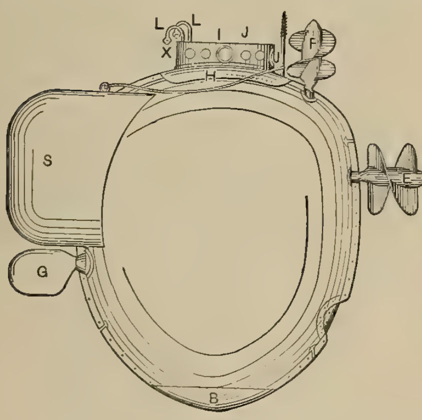
"An aperture, *N*, at the bottom, with its valve, was designed to admit water for the purpose of descending, and two brass forcing-pumps, *Q*, *P*, served to eject the water within when necessary for ascending. At the top there was likewise an oar, *F*, for ascending or descending, or continuing at any particular depth. A water-gauge or barometer, *C*, determined the depth of descent; a compass directed the course, and a ventilator within supplied the vessel with fresh air when on the surface.

"The entrance into the vessel was elliptical and so small as barely to admit a person. This entrance was surrounded with a broad elliptical iron band, the lower edge of which was let into the wood, of which the body of the vessel was made, in such a manner as to give its utmost support to the body of the vessel against the pressure of the water. Above the upper edge of this iron band there was a brass crown or cover, resembling a hat with its crown and brim, which shut water tight upon the iron band; the crown was hung to the iron band with hinges, so as to turn over sidewise, when opened. To make it perfectly secure when shut, it might be screwed down upon the band by the operator or by a person without.

"There were in the brass crown three round doors, *J*, one directly in front and one on each side, large enough to put the hand through. When open, they admitted fresh air. Their shutters were ground perfectly tight into their places with emery, hung with hinges, and secured in their places when shut. There were likewise several small glass windows in the crown, for looking through and for admitting light in the day time, with covers to secure them. There were two air pipes, *L*, *L*, in the crown. A ventilator within drew fresh air through one of the air pipes and discharged it into the lower part of the vessel; the fresh air introduced by the ventilator expelled the impure light air through the other air pipe. Both air pipes were so constructed that they shut themselves whenever the water rose near their tops, so that no water could enter through them, and opened themselves immediately after they rose above the water.

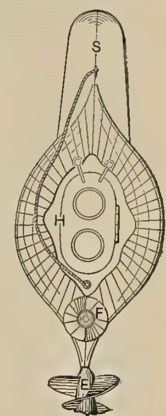
"The vessel was chiefly ballasted with lead, *B*, fixed to its bottom; when this was not sufficient, a quantity was placed within,—more or less, according to the weight of the operator. Its ballast made it so stiff that there was no danger of oversetting. The vessel, with all its appendages and the operator, was of sufficient weight to settle it very low in the water. About 200 pounds of the lead at the bottom for ballast could be let down 40 or 50 feet below the vessel; this enabled the operator to rise instantly to the surface of the water in case of accident.

"When the operator would descend, he placed his foot upon the top of a brass valve, depressing it, by which he opened a large aperture in the bottom of the vessel, through which the water entered at his pleasure; when he had admitted a sufficient quantity, he descended very gradually. If he admitted too much, he ejected as much as was necessary to obtain an equilibrium by the two brass forcing-pumps, which were placed at each hand. Whenever the vessel leaked, or he would ascend to the surface, he also made use of these forcing-pumps. When the skillful operator had obtained an equilibrium, he could row upwards or downwards or continue at any particular depth, with an oar placed near the top of the vessel, formed upon the principle of the screw, the axis of the oar entering the vessel. By turning the oar one way he raised the vessel; by turning it the other, he depressed it.



SIDE VIEW OF BUSHNELL'S BOAT.

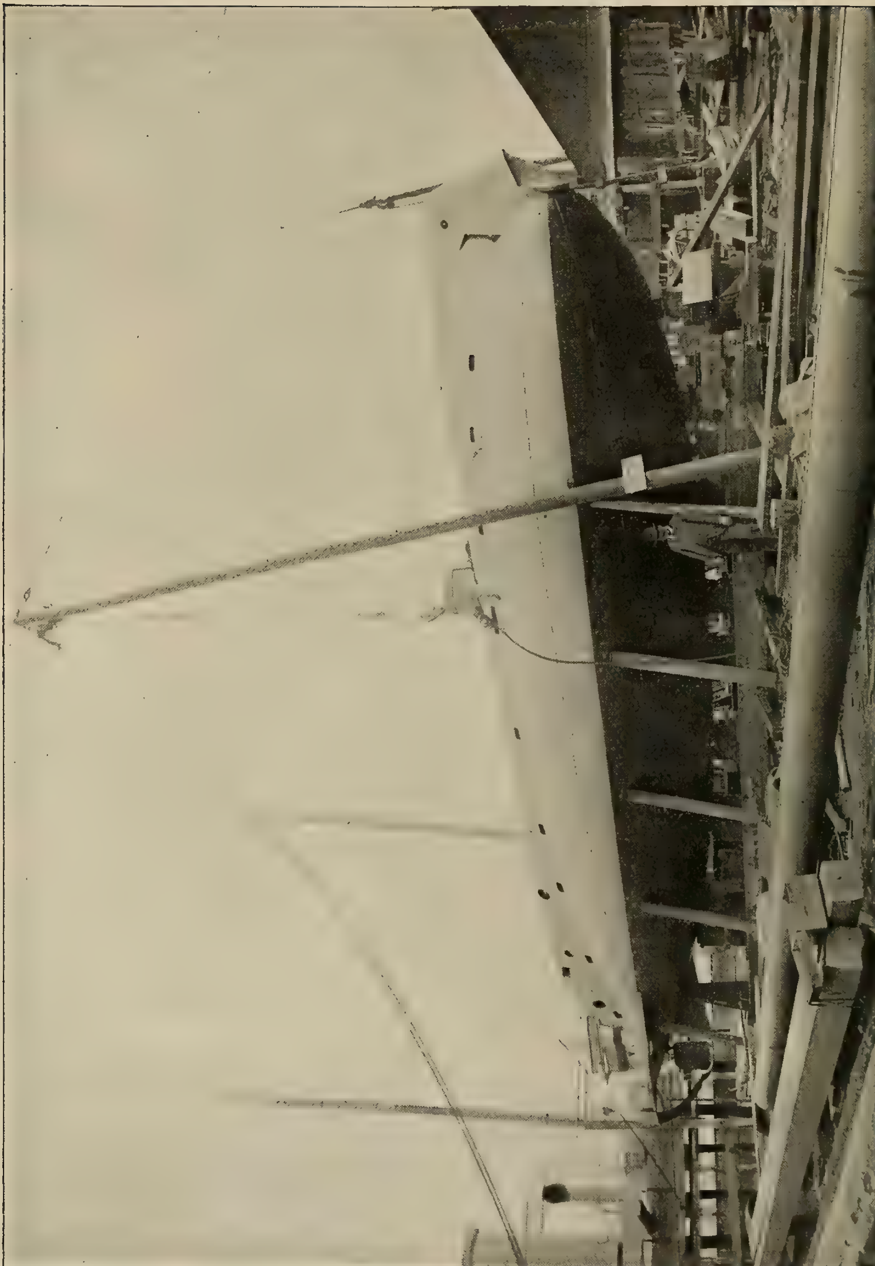
"A glass tube, 18 inches long and 1 inch in diameter, standing upright, its upper end closed and its lower end, which was open, screwed into a brass pipe, through which the external water had a passage into the glass tube, served as a water-gauge or barometer. There was a piece of cork, with phosphorus on it, put into the water-gauge. When the vessel descended, the water rose in the water-gauge, condensing the air within and bearing the cork with its phosphorus on its surface. By the light of the phosphorus the ascent of the water in the gauge was rendered visible, and the depth of the vessel under water was ascertained by a graduated line.



END VIEW.

"An oar, *E*, formed upon the principle of the screw, was fixed in the forepart of the vessel; its axis entered the vessel, and, being turned one way, rowed the vessel forward, but being turned the other way, rowed it backward. It was made to be turned by the hand or foot.

"A rudder, *G*, hung to the hind part of the vessel, commanded it with the greatest ease. The rudder was made very elastic, and might be used for rowing forward. Its tiller was within the vessel, at the operator's right hand, fixed at a right angle on an iron rod which passed through the side of the vessel; the rod had a crank on its outside end which commanded the rudder by means of a rod extending from the end of the crank to a kind of tiller fixed upon the left hand of the rudder. Raising and depressing the first mentioned tiller turned the rudder as the case required. A compass, marked with phosphorus, directed the course both above and under the water, and a line and lead sounded the depth when necessary.



THE HOLLAND SUBMARINE BOAT JUST BEFORE LAUNCHING AT THE CRESCENT SHIPYARD, ELIZABETHPORT, N. J.

"The internal shape of the vessel, in every possible section of it, verged towards an ellipse as near as the design would allow, but every horizontal section, although elliptical, was as near to a circle as could be admitted. The body of the vessel was made exceedingly strong, and to strengthen it as much as possible, a firm piece of wood was framed parallel to the conjugate diameter, to prevent the sides from yielding to the great pressure of the incumbent water in a deep immersion. This piece of wood was also a seat for the operator.

"Every opening was well secured. The pumps had two sets of valves. The aperture at the bottom, for admitting water, was covered with a plate perforated full of holes to receive the water and prevent anything from choking the passage or stopping the valve from shutting. The brass valve might likewise be forced into its place with a screw if necessary. The air pipes had a kind of hollow sphere, *X*, fixed round the top of each to secure the air pipe valves from injury; these hollow spheres were perforated full of holes for the passage of the air through the pipes. Within the air pipes were shutters to secure them should any accident happen to the pipes or the valves on their tops.

"Wherever the external apparatus passed through the body of the vessel the joints were round and formed by brass pipes, which were driven into the wood of the vessel; the holes through the pipes were very exactly made, and the iron rods which passed through them were turned in a lathe to fit them. The joints were also kept full of oil to prevent rust and leaking. Particular attention was given to bring every part necessary for performing the operations, both within and without the vessel, before the operator, and as conveniently as could be devised, so that everything might be found in the dark, except the water-gauge and the compass, which were visible by the light of the phosphorus, and nothing required the operator to turn to the right hand or to the left to perform anything necessary.

"In the fore part of the brim of the crown of the vessel was a socket, and an iron tube passing through the socket. The tube stood upright, and could slide up and down in the socket six inches. At the top of the tube was a wood screw, fixed by means of a rod which passed through the tube and screwed the wood screw, *R*, fast upon the top of the tube. By pushing the wood screw up against the bottom of a ship and turning at the same time, it would enter the planks; driving would also answer the same purpose. When the wood screw was firmly fixed, it would be cast off by unscrewing the rod which fastened it upon the top of the tube.

"Behind the submarine vessel was a place, above the rudder, for carrying a large powder magazine, *S*. This was made of two pieces of oak timber, large enough, when hollowed out, to contain 150 pounds of powder with the apparatus used in firing it, and was secured in its place by a screw turned by the operator. A strong piece of rope, *H*, extended from the magazine to the wood screw above mentioned, and was fastened to both. When the wood screw was fixed and was to be cast off from its tube, the magazine was to be cast off likewise by unscrewing it, leaving it hanging to the wood screw. It was lighter than the water, so that it might rise up against the object to which the wood screw and itself were fastened.

"Within the magazine was an apparatus, *T*, constructed to run any proposed length of time under twelve hours; when it had run out its time, it unpinioned a strong lock, resembling a gun lock, which gave fire to the powder. This apparatus was so pinioned that it could not possibly move, till, by casting off the magazine from the vessel, it was set in motion.

"The skillful operator could swim so low on the surface of the water as to approach very near a ship in the night without fear of being discovered, and might, if he chose, approach the stem or stern above water with very little danger. He could sink very quickly, keep at any depth he pleased, and row a great distance in any direction he desired without coming to the surface. When he rose to the surface he could

soon obtain a fresh supply of air, and then, if necessary, he might descend again and pursue his course."

This invention was never successfully used, the principal difficulty being to find a skillful operator; but the nearest approach to success was in an attack on the *Eagle*, a British sixty-four gun ship, lying off Governor's Island, in New York harbour. The operator succeeded in getting under her and attempted to fasten a screw into her bottom, but struck, as he supposed, a bar of iron. Not being well skilled in the management of the craft, in attempting to seek another place, he lost the ship, and was unable again to find her; he therefore cast off his magazine and made off. An hour afterward the magazine exploded some distance from the ship, throwing up a huge column of water, greatly to the consternation of those on board, who were unable to ascertain the cause of so singular a phenomenon.

The writer has been thus particular in describing this invention because it seems, notwithstanding its failure, to have been the most perfect thing of its kind constructed before 1880. Considering the disadvantages Bushnell must have laboured under at the time (it occupied him from 1771 to 1775 to complete the boat) he has well earned his title of "father of submarine warfare."

The failure to fasten the screw into the bottom of the *Eagle* was most probably owing, not to its having encountered a bar of iron, but to want of pressure enough against the screw to cause it to enter the wood. Had the operator thought of dropping his 200 pound weight to the bottom while trying to insert the screw, he would probably have succeeded in destroying the great battle ship. The most important feature of the "American turtle" was that it was made small enough to be propelled at fair speed, and managed by one man.

The following notes on Fulton's submarine boats are copied from a paper by Captain Maguire, United States Army, in the Report of the Board of Fortifications, 1866:—

"Fulton, borrowing the ideas of Bushnell, made a fairly good attempt at submarine navigation. He went to Paris in 1797 to solicit the support of the French Directory, but his projects, having been referred to the Minister of War, were by him deemed impracticable. The American engineer was not discouraged; he made a mahogany model of his proposed boat and presented it anew to the Directory, which then appointed a commission to examine it. This commission reported favourably, but the Minister of Marine positively refused to recommend its adoption. After three years of vain solicitation Fulton found the opportunity of offering his services to Napoleon, who entertained them, and commissioned Volney, Monge, and Laplace to make a thorough test of the submarine boat, and the sum of 10,000 francs was ordered to be paid to Fulton to defray the expenses of the experiments.

"On the strength of that encouragement, Fulton, in 1800 and 1801, built a diving boat which was propelled by two parallel screws. It was made to descend and ascend by means of screws which worked vertically. The experiments were made, first at Rouen, then at Havre. Thence Fulton went to Brest. During that journey he greatly disturbed the cannoneers of the coast batteries, who saw him suddenly disappear under the water to reappear a few moments later on the surface.

"Soon afterwards he built at Paris a second boat, more elegant than the first, and which bore proudly on its taffrail, in letters of gold, the name *Nautilus*. This new diving boat had iron ribs and was sheathed with copper. It was of an elongated ovoidal form. On the deck was a groove in which lay a small mast which could be shipped by means of a hinge. In the interior, which was about 6 feet in diameter, were the handles of the oars, which were arranged in the form of a screw. A reservoir, into which water was introduced, caused the *Nautilus* to descend at will; a force pump expelled the water and allowed the boat to ascend.

"Finished in June, 1801, the *Nautilus* was tried on the Seine, above the Hotel des Invalides. Fulton having

shut himself up in his boat, with a sailor, carrying a lighted candle, descended under water, remained there for twenty minutes, and emerged after having gone a considerable distance. He again descended in order to regain the point of departure. He then reappeared at the surface and sailed several stretches, amid the applause of the assembled multitude.

"The experiments were continued at Brest. The following is an extract from the report of the naval officers charged with observing his experiments:—

"'On July 3, 1801, the engineer, accompanied by three men, went aboard of his boat in the harbour of Brest; he descended to the depth of 25 feet, and remained under water for an hour, moving in all directions at will. On July 24 he replaced his candle, which consumed too much of the respirable air, by an opening in the top of the boat, fitted with thick glass, which allowed sufficient light to penetrate to enable him to count the minutes by his watch. On the 26th he adapted to the *Nautilus* a mast, a large sail, and a jib. Suddenly, in the middle of the harbour, he struck the sails and mast and prepared to descend. His preparations consumed in all only two minutes. The boat had a speed under water of one metre per second; it was under perfect control, and could be handled as well as on the surface. The compass at no depth whatever lost any of its magnetic properties. On the 7th of August following there was a final experiment. Fulton carried in his boat a cubic foot of compressed air and remained under water four hours and twenty minutes.'

"By direction of the commission a small vessel was provided and Fulton directed to destroy it. He placed under the vessel, by means of the *Nautilus*, a torpedo which blew it into fragments.

"Notwithstanding this success the French Government did not think it ought any longer to encourage submarine navigation. Besides, Napoleon grew tired of waiting for the accomplishment of certain improvements which were judged necessary. Victim of his own impatience, he finally declared the invention impracticable. Eignt years later, however, he had the Coessin Brothers build a small diving boat, which bore the name of *Nautile*, and which was tried at Havre. A committee of the Institute, composed of Biot, Monge, and Carnot, was ordered to make a report upon the boat. The three savants reported as follows:—'There is no longer any doubt that submarine navigation may be established very expeditiously and at little cost.' The report of the commission bears the date of April 11, 1810. The report was published and commented on by competent men, notably Castera, but found no echo.

"In Niles' Register there is an account of a submarine boat and a description of a chase in which the vessel escaped her pursuers by diving like a porpoise. From the description given, this boat does not appear to have differed much from Bushnell's boat.

"Fulton always had faith in the future of his work. Repulsed by France and also by England, he returned to America, where he undertook the construction of a new submarine boat which his death, in 1815, prevented him from completing. That boat, called *The Mute*, was 80 feet long, 22 feet wide, and 14 feet deep. Its hull was a foot thick. The deck was covered with iron plates. It was intended that the boat should habitually run on the surface like ordinary boats, but on approaching the enemy, it was to dive quickly under the water."

If some one of the large number of experimenters who endeavoured to construct submarine boats since that time had contented himself with closely copying the valuable features of Bushnell's vessel, instead of starting out with radically new and untried plans, and without having any experience to guide him, we should have had success to record instead of an almost unbroken list of failures.

During the period that elapsed from Fulton's time to the American Civil War, several submarine boats were constructed, scarcely any of which made more than one or two poor attempts at

operating under water. Phillip's boat, launched in 1851, on the waters of Lake Michigan, may be considered an exception. He is said to have taken his wife and two children with him, and spent a

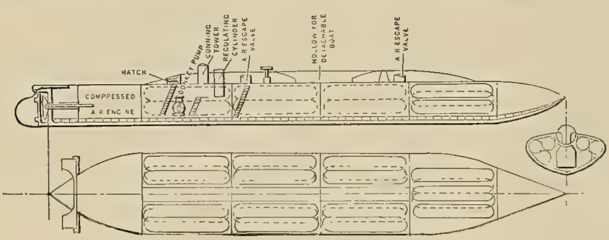
PHILLIP'S BOAT.

whole day exploring the bottom of the lake. It is said that he also had a 6-pounder gun mounted in this boat, and, with it, descended, and fired shot up through the bottom of hulks that had been anchored for that purpose.

His vessel was cigar-shaped, 40 feet long, and 4 feet in greatest diameter,—that is, its length was ten times greater than its diameter. It had curved ends and a straight, cylindrical middle body. Water tanks ran fore and aft in the cylindrical portion of the boat, on each side, and on the bottom.

THE CONFEDERATE BOAT USED IN THE AMERICAN CIVIL WAR.

In 1863 Admiral Bourgois, of the French Navy, experimented with a submarine boat named *Le Plongeur*, designed by Charles Brun, a naval constructor. It was of the form of a large fish, but flattened for one-third of its circumference on its upper surface. It was 146 feet long, and 12 feet deep (equal in length to over twelve times its depth). Its draft was 9 feet, and it exposed about 3 feet of the depth of its body when floating on the surface. It was propelled by an eighty horse-power engine, driven by compressed air, held in a large number of horizontal tubular reservoirs. The water to cause submergence was carried in long reservoirs placed under the air tubes.



LE PLONGEUR '

A certain portion of the turtle back of this vessel could be detached, in an emergency, to form a life boat for the crew of twelve. Although it was reported in 1864 that the experiments were concluded in a satisfactory manner, we have the announcement of the late head of the French Navy, M. Bourgeois, that all French attempts, including *Le Plongeur*, and her successors, *Gymnote* and *Zedè*, were failures.

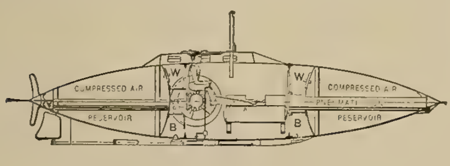
So much secrecy has been maintained regarding these vessels that it cannot be told for certain in what particulars they were defective. Yet it is known that in the case of *Le Plongeur*, at least, the conditions favoured a movable centre of gravity. This was probably also the case with the *Gymnote*, which was 10 diameters in length.

The submarine boat that destroyed the United States steamer *Housatonic* in Charleston harbour during the American Civil War was built by Messrs. McClintock & Howgate. It was about 50 feet long, and elliptical in transverse section. Its crew consisted of nine men, eight of whom propelled the vessel by operating cranks on the screw shaft; the ninth was the pilot. It was designed to make the attack by passing under the keel of a ship, towing a contact torpedo having a small reserve buoyancy. Under favourable conditions the torpedo would be drawn under water when the vessel descended, strike the bottom of the ship, and explode on contact.

During the attack on the *Housatonic* on February 17, 1864, the vessel did

not run under water. The crew submerged it to the hatch coaming and left the cover open against the protest of Mr. Howgate, who dispatched it on its last mission. On that occasion it was armed with a torpedo on a spar that projected fifteen feet from the stem. The wave thrown up by the explosion of the torpedo, when it struck the *Housatonic*, entered the open hatchway and swamped the vessel, drowning the crew. This was the fourth crew drowned in the same vessel, thirty-two of the thirty-six men who formed the four crews having perished through carelessness or accident.

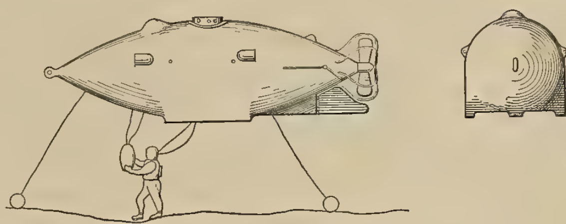
After the Civil War the first submarine boat that gained any attention in the United States was the *Intelligent Whale*, a vessel 26 feet long by 9 feet deep, built in Newark, N. J., by General Hoxsey. The value of this vessel was never properly ascertained. Great difficulty was experienced in getting a crew to man her for her first test in Newark Bay, and it is probable that she would have lain long untried had not the late General Sweeney persuaded two other persons to venture with him. They dived where the water was about sixteen feet deep. Clad in a diver's suit General Sweeney passed out through a manhole in her bottom,



THE "FENIAN RAM."

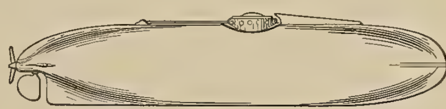
placed a torpedo under a scow, anchored there for the purpose, and, after re-entering the boat and moving away to a safe distance, exploded the torpedo by a lanyard and friction primer and blew the scow to pieces. The boat was bought by the United States Government, and a trial was made in 1872, which proved a complete failure. She is now preserved as a curiosity at the Brooklyn Navy Yard.

Interest in submarine boats was again stimulated by the success of the *Fenian Ram* in the United States. This boat was so named by a facetious reporter who was annoyed because he could not get all the information he wanted. It was launched on the Hudson river at New York, in April, 1881. The experiments made with it, threw a great deal of light on the subject of submarine



THE "INTELLIGENT WHALE."

work. It was proved that guiding the boat by direct vision while submerged was impracticable, that steering a straight course under water, although not regarded as a difficulty by any one



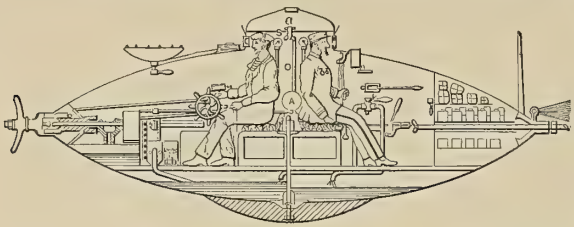
TUCK'S BOAT.

up to that date, was a problem that must be solved before submarine warfare could be made practicable under modern conditions.

Another of the lessons taught by experiments with this vessel was that even though it were possible to find an anchored ship by searching for her under water, it was not possible to find either the vulnerable point or any other particular point in the vessel's hull, nor even to be certain in what direction it lay from the boat while it was underneath the ship. All that the operator could tell certainly was that he passed into a dark shadow when he got under the ship, and he could not tell how many feet of space intervened between him and the ship's hull. In a very few

moments of this experience he realised that if his boat rose upwards against the ship's bottom, or collided with screws, rudder, or bilge keels, his little vessel would assuredly be crushed like paper, leaving him no possible chance for escape. No further demonstration was needed to satisfy him that if the ship were moving, and her propellers spinning around rapidly, it would be insane rashness to bring his vessel near enough to be crushed by collision with the ship, or to have himself and his boat cut to pieces by her screws. Very clearly, a submarine boat must make its attack from a distance by employing either projectile or automobile torpedoes.

About twenty experimental vessels have been built in the United States and in Europe since the last trials of that vessel, with but indifferent success, if we are to judge by the action of the late head of the French Navy, who, following the example of the United States Navy Department, instituted a competition for designs for a submarine boat, because hitherto the efforts of his government to obtain or construct an effective vessel had not been successful.



A SECTION OF GOUBET'S BOAT.

Even though full particulars of the writer's experiments were published in the newspapers of 1881-3, yet, by some mischance, the designers of the new boats took no notice of them, or failed to see and utilise them. Had they even closely copied the important features of Bushnell's boat, a description of which was published by Commander Barber, United States Navy, in 1882, instead of starting out with radically new plans, and no experience to guide them, the advertisement of the French Minister of Marine would not now be necessary; but unfortunately, each one happened on a possibly good idea, and, believing that that alone was essential, hastened to build a boat around it, and failed.

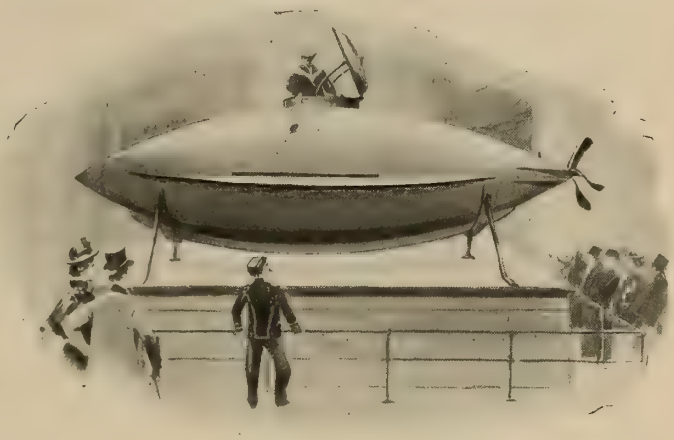
A majority of modern designers also set undue importance on some very trifling matters that appear to them to be vital and sacrifice valuable qualities in order to attain them. For example, it is worse than useless to provide that the boat shall always descend and rise on an even keel, no matter how rapidly these movements may be performed, as no submarine torpedo vessel will ever be required, while in service, to lie still at any given level, or to rise or descend a little on an even keel. A few dives in an actual submarine boat would clear away many of the imaginary difficulties and plainly show those that must be encountered and provided against.

Of the French submarine boats, built by M. Goubet, of Paris, a number of descriptions have been published. According to one of these, in *Engineering*, of London, the first of these boats was completed in 1881, and led to an order from the Russian Government for the mechanism of three hundred similar ones, of which fifty were built at Paris, and delivered early in 1883.

The hull of the boat can be opened at the upper part to admit the entrance of the officer and man who form her crew. These two having taken their places, the hatch is covered by a dome, secured by hinges and bolts, a joint being made by the edges going into a recess lined with india rubber. There are seven glazed openings in the hull, each covered by glass half an inch thick, and further protected by an external grating and internal shutter. Near the stern of the boat is placed the torpedo, containing 110 pounds of dynamite or other explosive. This is fastened by a catch-joint which can be operated from the interior of the boat. The torpedo is attached to a conducting wire wound on a drum.

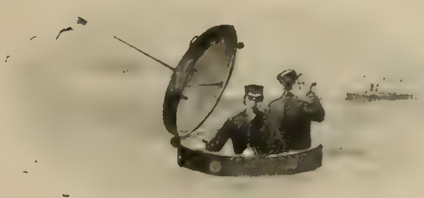
In the interior of the boat are a reser-

voir of compressed air, which serves as a seat for the men; the propelling mechanism, consisting of electric accumulators, a dynamo, and oars; a pump for removing water from the reservoirs when the boat has to rise; an air pump for expelling the vitiated air; and a double-acting pump which preserves the stability of the vessel by the aid of two reservoirs and of a pendulum. The water reservoirs serve to effect the immersion of the boat, and are each divided into several compartments to prevent the water in them from surging backwards and forwards.



"LE GOUBET."

The sailor opens a cock to permit the compressed air to flow into the boat. The air passes through the water reservoirs, in order to become saturated with humidity, and enters the dome. A gauge indicates the pressure in the reservoirs. The pump is put in action to expel the vitiated air. The man then starts the boat at the line of flotation and the officer directs its course. When it has arrived under the hostile ship, which may be seen through the upper window of the dome, the boat is ma-



TAKING AN OBSERVATION FROM "LE GOUBET" AWASH.

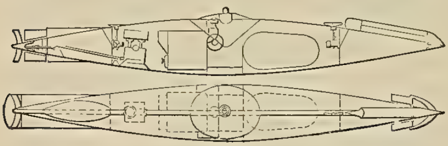
nœuvred so as to obtain the best position, and then the torpedo is cast off to ascend by its flotative power, and attach itself to the vessel by its impact and a ring of spikes which it carries at its upper part. This done, the boat withdraws, paying out the conducting wire until a safe distance has been gained, say 100 or 150 yards. The circuit is then completed, and the explosion effected by electricity.

An explosive signal forms a means of communication with the surface in case any accident should occur to the craft and prevent it from rising, indicating by the loudness of the noise and the colour of the flame the depth to which the boat has descended. It may also carry up with it a telephone wire, to form a means of communication if desired. Another safety appliance is found in a large weight, fixed to the bottom of the boat and secured by a steel screw, which engages with a nut let into the body of the weight. Should an accident occur to the skin of the craft, or some necessity for a very rapid ascent to the surface present itself, the bolt is turned by a wrench until it withdraws itself from the nut, when the weight drops off, and the buoyancy of the boat carries her quickly to the surface in spite of the water in the reservoirs.

Air, compressed to fifty atmospheres, is carried in sufficient quantity to supply the two men for ten hours. The carbonic acid given off by them during that time is absorbed by 1500 grammes of caustic potash, distributed in various parts of the boat. A slight amount of

free chlorine serves to destroy any other exhalations. In case the electric motor should break down, oars are provided. Two men are able to row the boat at the rate of three miles an hour when fully immersed. In the Russian boats the power was obtained by treadles worked by four men.

Early in 1890 another boat, constructed by M. Goubet, was tested by the French Government, at Cherbourg, with favourable results; yet notwithstanding the fact that two of his boats, built on a larger scale, and considerably improved, were purchased last year by the Brazilian Government, M. Bourgeois, the late Minister of Marine, included them in his list of French failures. It may be noted also that although the Russian Government was provided with many of these vessels, yet none of them



NORDENFELDT'S BOAT.

were employed in the Russo-Turkish war; still there was every opportunity of doing so. The chief difficulties experienced with it appear to have been unsteadiness and uncertainty of direction in steering while afloat and submerged, and want of stability in the longitudinal direction while submerged.

Notwithstanding these easily remedied defects the boat was greatly superior to most of her predecesors and to some of her successors, as she was apparently free from the too common defect of a movable centre of gravity.

The boat designed by Nordenfeldt, of machine-gun fame, was cigar-shaped, with a low glass cupola on top. It is much larger than the Goubet boat, measuring, as it does, 64 feet in length by 12 feet beam, and 11 feet depth. The hull is of steel, averaging about one-half inch thick, on strong angle-iron frames. There is a set of balanced rudders, actuated by a pendulum within the hull, which keep it always horizontal and steady, while two small propellers, placed in sponsons on either side, and worked by steam, carry it down to any required depth. As the boat at once rises to the surface unless kept down by steam power, an accident to the machinery would immediately carry her up; yet, to guard against the extra danger of leakage, eight tons of hot water can be blown out, so that she then cannot fail to rise. There is also an ingenious automatic apparatus for causing the vertical propellers to stop when a given depth is reached, and to start again when the boat rises. Four men have been shut up six hours in the boat without inconvenience, but three are sufficient, and crews seem more willing to go in her on account of the use of an ordinary steam motor and the provision for breathing ordinary air. The boat has travelled on the surface 150 miles without recoaling.

At a trial of a Nordenfeldt boat, several years ago, as reported in the London *Times*, nearly 140 officers, representing all the European powers, were present. They seemed to be specially impressed with the contrivance for keeping an even keel by means of the balanced bow rudders, which, being out of the reach of the crew, could not be made useless by neglect or loss of nerve. The boat went down four times in succession to show the ease of working the vertical propellers, the last time staying five minutes at a depth said to be sixteen feet below the surface. In a very rough sea she showed her handiness in steering. After the crew were shut up three hours, they exhibited no signs of having been inconvenienced. During one day's trial the boat made a run of twenty miles at the surface, with the cupola and a little of the turtle back showing.

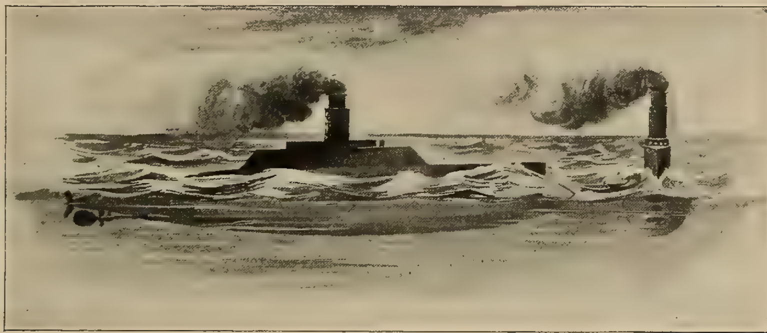
The London *Army and Navy Gazette* at the time gave the following account of a simulated attack on the tug *Svea*:—

"When starting, the boat was on the surface, and while advancing she slowly descended, so that when about 1800 or 2000 yards from the *Svea* only half the cupola (about nine inches) would be seen above water. At this level she advanced until about 1000 yards from the

Svea, when she descended entirely under the surface and advanced altogether unseen for 400 or 500 yards, which occupied four and a half minutes. During the remainder of the distance the boat rose to the surface and descended again four times while still advancing, until within some 200 yards of the *Svea*, —a supposed certain striking distance for any Whitehead torpedo,—when the boat came to the surface and turned around; the crew, opening the cupola, came outside, and the experiments were finished."

She was sold to the Greeks early in 1886, who did not seem eager to practically test her qualities themselves, though in the presence of a committee Mr. Nordenfeldt's agent carried out the various conditions imposed. But the principal object of a submarine boat is to project a locomotive torpedo, and this boat having tnen no means of doing so, the Greeks desired this might be added before the purchase was concluded.

Mr. Nordenfeldt's original idea seems to have been to have a tube on the outside of the boat forward, in which the torpedo should be placed, its discharge being effected, when desired, by simply admitting air to the engines. The torpedo would then propel itself out of the tube, to which the water had free access. This would, of course, entail some system of levers worked from the interior through a water-tight joint. On Greece obtaining the boat described, Turkey ordered two of the larger ones, which are understood to have been delivered.



THE HOLLAND SUBMARINE BOAT AWASH.

JUST BELOW THE SURFACE.

The defects that rendered these vessels practically useless were a movable centre of gravity, due to empty spaces in her large submerging tanks, and

steam space in her hot water tank, and to the want of an automatic system of compensation for weights expended. The French boats *Zedè* and *Gymnote*, the Spanish boat *Peral*, and two others built in Italy, were more or less successful, because they were propelled by electricity derived from storage batteries carried on board. This circumstance eliminated part of the cause of varying weight and movable centre of gravity; but their independence was also sacrificed as they could run for only about ten hours out of twenty-four, and they could never venture far from the station at which their batteries were recharged.

Several prominent officers of the United States Navy took a deep interest in the performances of the writer's second boat, even though, for the same old reasons,—to protect their discoveries,—its owners would not permit them to examine it or test it in operation. Lieutenant W. W. Kimball, of the Ordnance Bureau, United States Navy Department, investigated its work and the principles of its design. He succeeded, with the assistance of his colleagues, in convincing Mr. W. C. Whitney, who was then Secretary of the United States Navy, that the armoured torpedo boat, or its equivalent, which he so much desired, but which, he regretted, could be scarcely more than visionary, was proved, by these experiments, to be attainable.

Three public competitions were held by the Navy Department, each resulting in favour of the design which was finally accepted in February, 1895, after having been, with some intermissions, nearly ten years under consideration. This long delay was owing to the opposition of a few officers of conservative spirit who would prefer to see the value of submarine boats fully established by their employment in other navies and their place in schemes of attack and defense properly located before they could recommend their adoption in our own navy.

Conservatism has thus far delayed the adoption of a most valuable offensive and defensive weapon, not because success was ever proved to be unattainable, but because some vessels, built by inexperienced inventors, happened to be failures. Bushnell's success counted for nothing, apparently because his experiments were made in the last century, but more probably because very little was known either of the design of the boat or of the conditions essential to success. The partial success of many others was unnoticed.

That any doubt should be entertained of the practicability of properly designed submarine boats is remarkable in view of the fact that the United States Navy Department was satisfied with the proofs of the efficient performance of the writer's experimental vessel. The Whitehead torpedo is simply a submarine boat that runs at high speed in a certain direction, and that regulates its own depth of immersion automatically; and it does these things fairly well within a given range,—about 400 yards. It is not clear why a much larger boat, on the same lines and in similar conformity with the principles governing trim, stability, and manipulation, should not be equally successful. The similarity was wanting in all the modern failures, but those that were even partially successful were virtually similar in most of the essentials.

The substitution of intelligence for automata in controlling the propelling and directing mechanism of the boat, instead of marring its efficiency, renders its action reliable and certain. For example, the deviation from a straight course that occurs with the Whitehead torpedo after a certain length of run, could be corrected by the pilot, and the boat put on the true course again without difficulty.

The value of a submarine boat will be more clearly appreciated by a comparison with the Whitehead torpedo, which is already accepted in all navies as a satisfactory and effective submarine boat. The torpedo has a range of from 800 to 1000 yards, and if it deviates from its course, it misses its object and is lost or wasted.

The submarine boat has a range of 1000 miles, and it comes near enough to the object of attack to leave no chance of missing it before it fires its torpedo.

The Whitehead cannot follow the enemy nor search for him, nor intercept him, as it can run for only one minute and in one direction. The submarine boat, however, can cruise in any required direction for a week together, with a single supply of fuel. By providing for the relief of its crew every day, and renewing its fuel supply when required, it can do patrol duty indefinitely.

The submarine boat is a small ship on the model of the Whitehead, subject to none of its limitations, improving on all its special qualities, excepting speed, for which it substitutes incomparably greater endurance. It is not, like other small vessels, compelled to select for its antagonist a vessel of about its own or inferior power; the larger and more powerful its mark, the better its opportunity.

Unlike ordinary vessels, its entrance to an enemy's port cannot be barred by torpedoes, as it can move amongst them unscathed, or countermine them, leaving the channel free for its friends; or it may enter alone to destroy the enemy's ships and docks, as well as the magazines or shore defenses within 1000 yards of deep water; but for this work it must be armed with an aerial torpedo thrower.

The boat now being built for the United States Government satisfies all the requirements detailed earlier in this article. It will have a length over all of 85 feet; diameter, 11½ feet, total displacement, 168 tons, and a light displacement of 154 tons. The guaranteed speed on the surface will be 15 knots; the speed awash, 14 knots, and submerged, 8 knots. At full speed the boat will have an endurance of 12 hours, and a radius of action of 1000 miles at slower speed. The endurance, when submerged, will be 10 hours, at a speed of 6 knots.

The boat will be propelled by triple screws, operated by three independent sets of triple expansion steam engines, capable of developing 1625 indicated horse-power. There will also be electric storage batteries and a motor of 70 horse-power for submerged running. The armament will consist of two expulsion tubes and five Whitehead torpedoes.

Steering on the horizontal plane, while submerged, is accomplished by an automatic apparatus that performed very well in one of this boat's predecessors. Steering in the vertical plane is also done automatically, and with considerable exactness, while submerged. Steering in both planes can also, at the same time, be controlled manually.

There will be a steel armour turret, four feet high, to protect the pilot and smoke stack, and the hull will be covered by 3 feet of water while the vessel runs awash to attack.

When engaged in harbour defense duty its position will be outside the outer line of harbour defenses—that is, beyond the range of the guns defending the entrance. While performing this duty it will lie awash—that is, with only the top of its turret over the surface of the water. On the approach of an enemy's vessel the smoke stack will be shipped and the aperture on top of the turret through which it passed will be quickly closed water-tight. She will then run in a direction to intercept the enemy's ship, still remaining in the awash condition until she comes near enough to be discovered by the lookouts on the ship, when she will go from the awash to the entirely submerged condition. The distance from the ship at which she must dive will depend on the weather. In rough weather she can come quite close without being observed.

Having come within a distance that the operator estimates at two or three hundred yards from the ship, the diving rudders are manipulated so as to cause the top of the turret to come for a few seconds above the surface of the water. During this short exposure of the turret,—much too short to give the enemy a chance to find its distance and train a gun on it capable of inflicting any injury,—the pilot ascertains the bearing of the enemy's ship, alters his course or makes another dive if necessary. If he finds that the submarine boat is within safe striking distance, say 100 yards, a Whitehead torpedo is discharged at the ship. A heavy explo-

sion within six seconds after the torpedo is expelled, will notify the operator that his attack has been successful, and he may then devote his attention to the next enemy's ship that may be within reach.

When the boat is running on the surface of the water, with full steam power, and it becomes necessary to dive quickly, the pilot gives the order "Prepare to dive." The oil fuel is instantly shut off from the furnace, the valves are opened to admit water to the water ballast tanks, an electric engine draws down the smoke stack and air-shaft into the superstructure, and moves a large massive sliding valve over the aperture on the turret through which the smoke stack passes. These operations will be completed in about thirty seconds, when the boat is in the awash condition and prepared to dive. In twenty seconds more it will be running horizontally at a depth of twenty feet below the surface of the water and quite beyond the reach of the enemy's projectile.

PRICE, 25 CENTS. $3.00 PER YEAR. FOREIGN COUNTRIES, $4.00.

Cassier's Magazine—September, 1897.

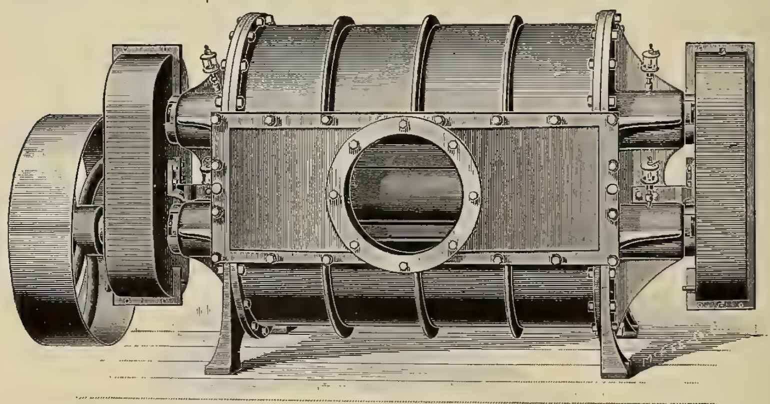
CONTENTS.

$3.00 per year. 25 cents per number. Entered at the New York Post Office as second-class matter.

☞ Index to Advertisements will be found on page 10.

ROOTS' ROTARY PRESSURE BLOWERS.

ONE TO TWELVE POUNDS PER SQUARE INCH.

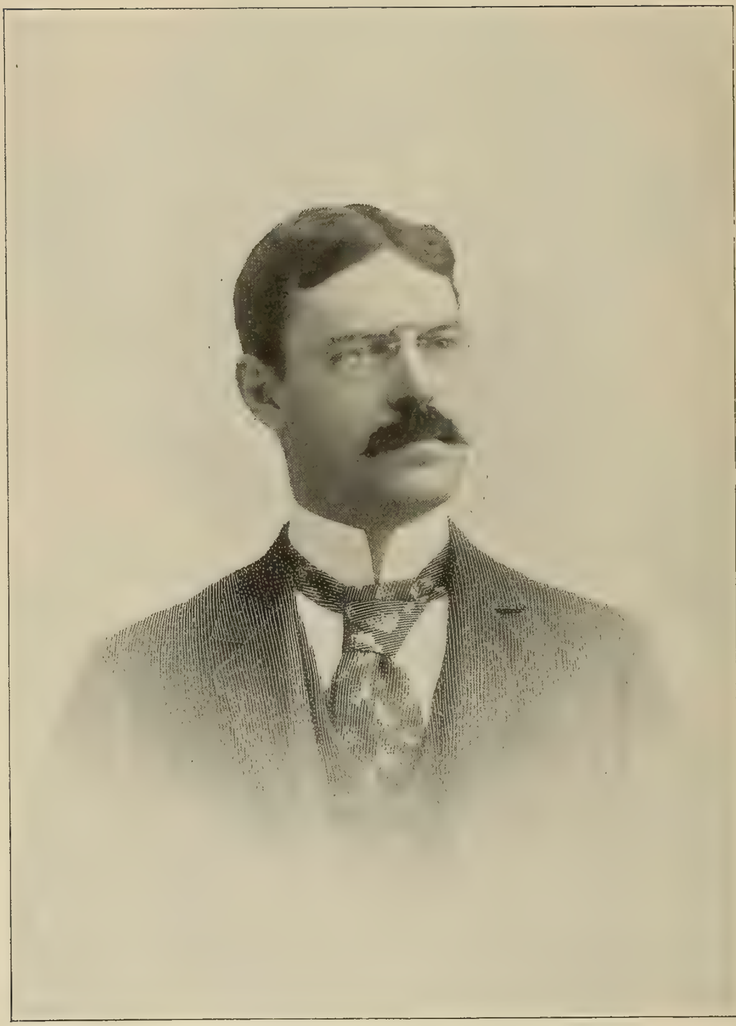


Highest Efficiency. Best Workmanship.
Greatest Economy of Power. Unequaled Durability.

P. H. & F. M. ROOTS CO.

Home Office:
CONNERSVILLE, IND.

New York Office:
109 LIBERTY STREET.



FROM A PHOTOGRAPH BY ALMSTÆDT, STATEN ISLAND.

Lewis Nixon.

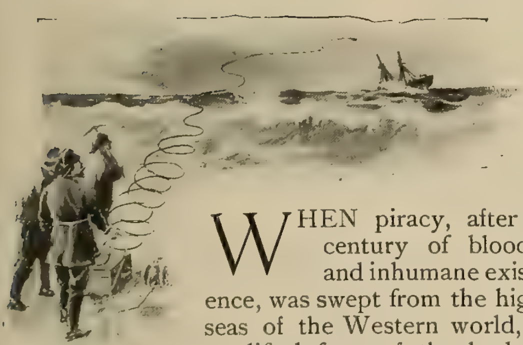
(See page 638.)

CASSIER'S MAGAZINE.

VOL. XII. SEPTEMBER, 1897. NO. 5.

THE EVOLUTION OF THE WRECKER.

By George Ethelbert Walsh.



WHEN piracy, after a century of bloody and inhumane existence, was swept from the high seas of the Western world, a modified form of the lawless commerce continued to flourish along isolated sections of the American Atlantic coast, threatening all shipping interests, and endangering the lives of those who travelled the ocean in wooden vessels. "Wrecking" was an exciting and adventurous calling, little less daring and bloody than red-handed piracy perhaps, but sufficiently cruel to attract many of the murderous spirits who had followed the *Jolly Roger* under Captain Kidd, Ned Low and Lafitte.

With the lowering of the black flag for the last time on the high sea, the dangerous Vikings, who had served under it, fled to secluded spots on the American coast, where they entered into the less hazardous occupations of smuggling and wrecking. Under the new impetus given to it by the re-enforcement of these ex-buccaneers, wrecking assumed an importance and danger to commerce that has been checked only within the past quarter of a century in the jurisdiction of the United States and at an expense of many lives and considerable money.

In a certain sense early salvage laws encouraged and protected the wreckers. One-third of everything that was saved from a wrecked ship along the coast went to those who risked their lives to rescue the vessel and its valuable cargo from the sea. This was the temptation that bred a hardy class of men along every dangerous shore, and its demoralising effect soon became so apparent that powerful agencies had to be enlisted to check and limit the abuses. The small profits that accrued from this source could not long satisfy those who made a business of saving disabled ships from the rocks and treacherous sand bars. The more daring members of the profession seized every part of the cargo of a vessel cast upon the shore, and the utmost vigilance of government officials often failed to save anything for the rightful owners.

From brave, self-sacrificing fishermen, the wreckers degenerated into greedy, unprincipled plunderers, whose chief concern in life seemed be to elude the officials, and to appropriate every part of a ship and her cargo in return for any heroism they displayed in saving the crew and passengers from a watery

THE BRITISH STEAMER "MONA'S ISLE," BEING HAULED OFF THE ROCKS BY THE LIVERPOOL SALVAGE ASSOCIATION.

grave. With their numbers strengthened by outlawed pirates, they became more reckless in their work, and the greed of plunder soon stifled any moral sense or human sympathy that they might have originally possessed. Amid the shrieks and pleadings of half-drowned passengers, they secured their booty, plundering even the bodies of the dead, and escaping to their isolated homes before the officers of the law could arrive upon the scene.

The work of the wreckers abounds in tales of cruel and murderous deeds,—in crimes that might make a pirate blush with envy,—but withal there were courage, self-sacrifice and oftentimes genuine acts of heroism to light up the record of guilt. The wreckers in the course of a few generations became hardy Vikings of the sea before whose skill and energy everything seemed possible. The tumbling surf and raging sea had no fear for them; they defied the storm and cold with a hardihood that should have been enlisted in a better cause. In the winter months they followed their piratical labours in the very teeth of terrific storms and blood-freezing blizzards, enduring sufferings and privations that would kill any less hardy spirits, and never once flinching from dangers and difficulties that seemed well-nigh insurmountable.

There is little wonder that romance and fiction have made the wrecker a central figure in many a tragedy and well-told tale, and that poet and artist have woven him into song and picture. There is sorrow and adventure enough on the sea in days of peace, but in times like those when the pirates and wreckers combined to worry and destroy the mariner, the tragedies were far more numerous and terrifying.

But the erection of systems of lighthouses, and the establishment of chains of life-saving stations, sounded the doom of coast wreckers. Approaching vessels could not fail to get within the

range of the warning lights that flashed their bright rays across the sea, and false beacons lost their old-time power for evil. No mariner, in view of the brighter light from the lighthouse, would be foolish enough to be misled by the wrecker's feeble imitation. On the Newfoundland coast, however, the wrecker still finds some favourable points where ill-starred ships that have been carried out of their course by the errant tides of the Gulf of St. Lawrence can be lured upon the beach and rocks. The hardy fishermen of this coast barely obtain a living from the products of the sea, and if they occasionally, in their desperation, plunder a vessel that has drifted in their way, the crime can be set down to their want more than to any unnatural greed.

In his evolution from a simple, heroic fisherman, bent upon saving human life and property, to a criminal, engaged in practices little less horrible than those that have stained the pages of the history of piracy on the high seas, the wrecker has ever been a picturesque figure. But at the period when his doom was sounded by the inauguration of new systems of coast protection, he suddenly lost the interest of romancers, and to-day the wrecker is practically an obsolete figure in literature.

But the term "wrecker" has not died with the men whose acts were the sole excuse for coining the word. It has passed through a strange evolution, and survives to-day to represent exactly the opposite of what was originally implied by it. The wrecker of modern times is interested only in the salvation of every vessel that approaches a coast in a disabled condition, and with the life-saving crews he divides the honour of rescuing human life and property from old Neptune. The dictionaries for the most part continue to libel him and his calling with the old-time definition that a wrecker is "one who plunders, wrecks, or collects goods cast ashore from wrecks." The only saving grace found in this definition is in the latter clause, but even that is questionable in its meaning. In "wreck-master" some consolation is found, for here we learn

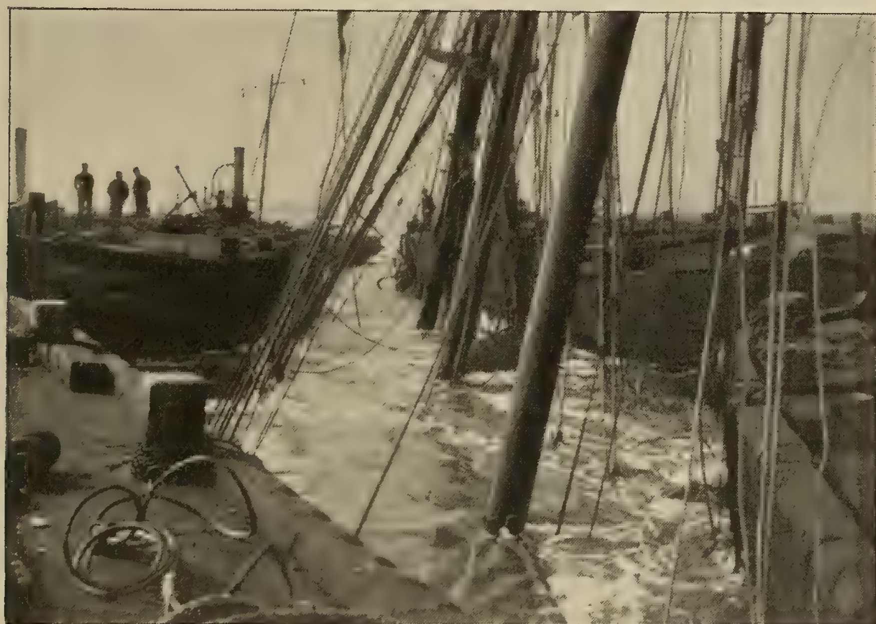


PHOTO BY NOAKES & NORMAN, GREENWICH, LONDON, S. E.
A SUNKEN VESSEL, SLUNG AND CARRIED BY THAMES CONSERVANCY, LONDON, LIGHTERS.

RAISING OF A BURNT SCHOONER BY THE CHAPMAN DERRICK AND WRECKING CO., NEW YORK.

that he is a " person who takes charge of the salvage from a wreck for the interest of the owners;" or, again, " a person appointed by law to take charge of goods, etc., thrown on shore after a shipwreck." The modern wrecker, or the " wreck-master " of a large wrecking company, is only partially defined in either of these descriptions.

The " wreck-master " of the old British law was appointed by the Crown to take charge of the salvage of vessels stranded upon the coast, and the " wreckers " were the inhabitants of the coast who plundered the stranded vessel before the authorities took possession of it. Thus " wreck " and " salvage " are described: — " When any ship or boat is stranded, or in sore distress on any shore or tidal water of the United Kingdom, any one assisting to save the lives of those in the endangered vessel, or to save the vessel itself, or its cargo, shall be entitled to receive from the owners a reasonable sum, besides expenses. This payment is called salvage. No receiver of wreck is entitled to salvage. Salvage on account of preservation of human life has priority to all other claims for salvage."

The wreck-master and the wreckers of to-day are volunteers in the service of humanity, working it is true for money, but with a will, energy, and scientific skill that make them indispensable aids to the life-saving service. Their deeds of bravery are often on a par with those of the old-time wreckers, who risked their lives for the paltry sums that they might plunder from the ship, lured upon the rocks by their false beacon lights. In the performance of their higher duties, the wreckers of to-day have rescued the word from the opprobrium that clung to it in the past, and have associated with it everything that is honourable and praiseworthy in life and property-saving at sea.

The trade of the wrecker assumes new importance in the eyes of the shipping world as it emerges from the barbarism of the last century and enters upon its present active and successful career, but the evolution is not com-

plete so long as new methods and machines are invented for saving human life and wrecks from the sea. In the nineteenth century the development of the wrecking industry has been co-extensive with the expansion of shipbuilding. The introduction of iron and steel steamships has vastly increased the labours of the wreckers, making their former machinery and lifting apparatus practically obsolete, and forcing them to the necessity of great changes in all departments in order to keep abreast of the times. The tremendous size of the modern ocean greyhounds, and even of the ordinary freight and tramp steamers, brought into existence problems for the wrecking companies to solve that required long experience and ingenuity in the service to be approached with any degree of success.

The business of the wreckers can be partly appreciated by one not familiar with the sea by glancing for an instance at some wreck statistics for 1895. According to Lloyd's Register, the gross reduction in the effective mercantile marine of the world for that year amounted to 1237 vessels, of 806,278 tons, excluding all vessels less than 100 tons. Of this total, 310 vessels, of 372,434 tons, were steamers, and 927, of 433,815 tons, were sailing vessels. Some of these vessels were not actually wrecked, but were broken up as old and worthless hulks. About 20 per cent. of the whole loss was from condemnation and dismantling; 40 per cent. of the total number of steamers and sailing vessels were stranded, or wrecked by similar casualties; 16 per cent. were lost from collision, and 15 per cent. from abandonment at sea.

In spite of elaborate lighthouse systems and excellent life-saving service, the total wreckage on the American coast runs high, and the wrecking companies have their time well employed. The statistics of the world's wreckage for a year shows merely the vessels that were not rescued by the wrecking company, and appears at first as a serious reflection upon the effectiveness of modern systems of wrecking. But this is not borne out by subsequent investigations. Most of the ships were either abandoned or wrecked at sea, and it is manifestly the business of the wreckers to lend a helping hand only when the vessel is along shore. The wrecking companies divide their work up into deep sea and harbour duties; but the former is never carried on very far from the coast, and generally within sight of the land. The vessels that become disabled at sea must look after themselves, or trust to the good fortune of meeting a companion ship which will give assistance.

PHOTO BY NOAKES & NORMAN, GREENWICH, LONDON, S. E.

A DIVER GOING DOWN TO A WRECK.

Owing to the high salvage money obtained by rendering assistance to a disabled ship at sea, many steamers and sailing vessels carry on an irregular sort of "wrecking business" by always being on the alert for stranded ships. A tramp steamer that could bring a great

transatlantic liner into port in a disabled condition would realise more money than its owner would make in a trip across the sea with a full cargo. As an illustration of what salvage money is paid for towing steamers into port, mention can be made of a few conspicuous cases. In 1882 the *City of Richmond* was towed into Halifax harbour, and cost her owners $35,000 (£7000) in salvage money. In the same winter the *City of Boston* broke her shaft at sea, and her owners were compelled to pay a bill, for towing and other aid, of $46,500 (£9300). When the Atlantic liner *Paris* broke down off the Irish coast in 1890, she was towed into port at an expense of $30,000 (£6000).

So rich are these prizes that the coast wrecking companies frequently send powerful tugs to sea just after a storm in search of disabled vessels. If a steamer is several days overdue, the tugs may go hundreds of miles off the coast, and in this sense the companies extend their labours into new fields, practising wrecking upon the high seas. This feature of the business is made possible by the construction of the modern powerful wrecking tugs, which can ride the roughest sea and tow a heavy steamer into port with ease, and as the science of wrecking advances we may have fleets of thoroughly-equipped wrecking boats to scour the ocean in every direction immediately after every storm. The value of this work would be inestimable.

It should not be surmised, however, that the wrecking companies are doing their noble work for humanitarian purposes. They are following up their duties for the money that can be lawfully made, and the extent and scope of their work will be extended just in proportion to the profits that they can see ahead. When general wrecking upon the high seas can be demonstrated as a profitable undertaking, there will, no doubt, be wreckers to enter into it with a will and energy. Meanwhile, naval cruisers, in times of peace, might be put to a profitable use in "wrecking" on the high seas after severe gales and win-

UNCOMFORTABLE QUARTERS.

A WRECKING STEAMER OF THE LIVERPOOL SALVAGE ASSOCIATION.

ter storms. The amount of property which they might save, might help largely to pay for keeping them in repair, not to speak of the lives which they might preserve.

In harbour wrecking the work is less dangerous and disagreeable than in deep-water wrecking, and a considerable part of the income of wrecking companies is derived from this source. In many guarded harbours and rivers collisions are inevitable, and no amount of carefulness can altogether prevent them. Property is constantly going to the bottom, and to rescue it from utter destruction the wrecking companies are ready at any moment to intervene. During the past eleven years the Thames Conservancy of London alone has raised about 70 vessels of about 100,000 tons in all, and over 300 barges. In addition to the Thames Conservancy there are in the United Kingdom salvage associations at Liverpool and Glasgow, all of them splendidly equipped and with records of excellent work done.

In the United States the two leading wrecking companies are located at New York, but their work is extended all along the Atlantic, and sometimes on the Pacific coast, including harbours and rivers. The plants of both the Merritt and Chapman companies are among the most complete in the world, and, although scientific wrecking may still be in its infancy, the equipment of these companies is such as to astonish an outsider. Wreck-raising was never considered possible until in recent times, especially when the vessel was constructed largely of steel and iron; but to-day the heaviest wrecks are not only raised from the bottoms of harbours, but sometimes from great depths in the sea. Speculative inventors have proposed various unique methods for raising sunken wrecks, having in mind the recovery of some of the historical and mythical fortunes that have gone to the bottom since the Spanish Armada was dispersed along the English coast and many of the richly-laden vessels found watery graves. But in practical wrecking circles these carbonic-acid, and air-balloon schemes, have received little attention; nor has any more been given to the stories of lost treasures whose authenticity has a reasonable

THE STEAMSHIP "PERTH," STRANDED ON BEACON ROCKS, DUNDEE, SCOTLAND. FLOATED BY THE BRITISH MARINE SALVAGE CO., LTD.

shadow of doubt. The wrecking companies have prepared their elaborate and expensive machinery and apparatus for special purposes that promise to return fair profits on the investment.

The perfection of the diving-bell has been an important factor in developing the efficiency of wreck raising. Work can be performed under water to a depth of 120 feet by means of the modern diving-bell. This depth was reached by the workmen in a diving-bell when the piers of the St. Louis bridge were built, and since then it has been repeated several times. It is rarely that wreckers have to go down to such an extreme depth, but if occasion demands it they are prepared for it. The heavy diving-bell of the wrecking companies is suspended by tackle from their lighters or tugs, and when it is necessary to place pontoons under the sunken wreck, several men go down at once. The bell is lighted by electricity, diffusing a bright light, so that the men can make their surveys intelligently.

The perfected diving-dress is used by the wreckers more generally than the bell, for it permits of better individual work, and enables the divers to perform ordinary labour quicker and more effectually. It is only in comparatively recent years that any kind of diving-dress was brought into practical form. The dress is made of india rubber, with a metal helmet, and glass circles for the eyes, and a rubber nozzle attachment for the air-pipe. Lead weights at the chest and back enable the diver to descend into comparatively deep water. He enters the water by means of a rope ladder, but a safety line and signal cord connect him with the men on the boat above. By means of this light and improved diving-dress, the man can explore the bottom and the interior of sunken wrecks, and unload the cargo. In the diving-bell the workmen cannot go beyond a certain confined space, and exploring shipwrecks at the bottom of the ocean is not easily performed in such a clumsy apparatus.

The modern diver of a wrecking company is generally a competent marine

engineer as well, and his duties are all-important and far-reaching. His knowledge of the general business of wreck-raising is second only to that of the captain of the company, and the latter is often an expert diver as well, having served his apprenticeship in this difficult and dangerous work. In times of emergency he puts on the harness himself, and descends to the wreck to satisfy himself of the accuracy of the situation. During the American Civil War the United States Government employed expert divers, who made reputations that have since been extended by successful work in the wrecking business. Captain E. R. Lowe, now engaged in coast-wrecking, with an office in New York, performed difficult feats for the Government in those troublesome days. When the Federal fleet sailed into Mobile bay, the harbour and river were thickly planted with torpedoes, and so ingeniously were they constructed that it was difficult to remove them. Captain Lowe, after spending considerable time in trying to remove them with his divers, finally decided to drag the bottom with a hawser of steel wire. As the torpedoes were pulled from their moorings, they exploded, and, although two tug boats were blown up in the efforts, the harbour was cleared so that the Federal ships could attack the forts with comparative ease.

The gunboat *Osage*, however, was sent to the bottom by the explosion o a torpedo, and Captain Lowe proceeded to raise her. The starboard bow was stove in, and the first bulkhead was badly shattered. The divers heroically explored the interior of the vessel under the very guns of the forts and shore batteries, and under the cover of darkness removed all the shot and shell from her. Then a temporary bulkhead was constructed in the place of the broken one, and by means of powerful pumps the water was withdrawn from her hold. After she was raised, the *Osage* was fitted out for service again, and she performed some brilliant deeds in the Federal cause.

The divers and many of the workmen connected with the Merritt Wrecking Company performed valuable service for the American Government in the Civil War. Captain Merritt, hale and hearty to-day at sixty-eight, undertook important jobs for the Federal authorities. His wrecking company was organised way back in the fifties, and it had already won some renown before the war broke out. One of the most important, or at least the most difficult, enterprises undertaken in those early days by the company in the interest of the Government was to raise the *Comanche* and *Aquilla* on the Pacific coast.

The monitors built by the Govern-

A DIVER IN ARMOUR.

ment were, in some respects, unseaworthy boats, and the Navy Department did not care to send them far out to sea after the loss of the first boat of that type off Cape Hatteras. But it was quite essential that a monitor should be stationed on the Pacific coast, and it was decided to attempt to transport one around Cape Horn in sections. The *Comanche* was selected for this purpose. She was taken apart, and the hull, tur-

ret plates, guns, ammunition, anchors, chains, and boats, were loaded upon the *Aquilla*, a large, heavily-timbered ship, capable of carrying a big load around stormy Cape Hatteras and Cape Horn. This queer experiment proved successful up to a certain point. The *Aquilla* reached San Francisco without accident, but through the negligence of some of the Pacific coast officials she was anchored directly over a sunken rock at Rincon Point, San Francisco. A gale sprung up after her arrival, and during the night and day she was anchored there she pounded a hole, twenty-nine feet long, in her bottom. She went down where she was anchored, with the *Comanche* on board, her stern protruding out of the water at low tide.

The Government was too anxious to have the monitor afloat in Pacific waters to abandon the two vessels to their fate at this juncture, and the Merritt Wrecking Company was therefore commissioned to raise them. Immediately the wrecking material necessary for the job was shipped overland from New York to San Francisco. Captain Merritt and his divers proceeded later to the scene of the accident. The heavy plates and turrets and ammunition of the *Comanche* were first removed, and then the hole in the bottom of the *Aquilla* was stopped. The water was pumped out of her hold, and enormous pontoons were chained to her sides. By means of these pontoons both vessels were raised, and the *Aquilla* returned to the Atlantic coast, while the *Comanche* was put together and made ready for service on her new station.

With but few exceptions, however, the work of the coast wrecking companies is confined entirely to the mercantile navy of the world. When a war ship gets in trouble, a sister ship is generally sent to her aid. But the aid of private wrecking companies might be invoked in moments of great peril. Should a war vessel sink off the coast, one of the leading wrecking companies would probably be engaged to do the

WRECKING PUMP SHED OF THE LIVERPOOL SALVAGE ASSOCIATION.

AN AMERICAN FERRYBOAT ON THE ROCKS.

work of raising her. In such a case a government would be subject to the same law of compensation as any private steamship company—that is, a board of underwriters would decide to how much salvage money the wrecking company was entitled. Usually to-day the steamship companies, in employing wrecking companies to raise a ship or to pull one off the shoals, stipulate a certain sum for the job, and the wreckers do not apply to the legal authorities to decide the amount of salvage. The amounts paid to the wrecking companies for their service appear at times to be exorbitant; but it is not only for the actual manual labour performed that they receive pay, but for their knowledge and experience, and for the expensive apparatus which they are forced to keep on hand.

Some instances of big sums paid to the wrecking companies can readily be recalled. When the fast Atlantic liner *New York* made her first voyage from the port of New York, she ran aground off Sandy Hook, and the owners had to pay nearly $100,000 (£20,000) to float her again. One of the Red D line steamers stuck on the Brigantine shoals off New Jersey, in 1889, and the wrecking company that pulled her off received $40,000 (£8000) for their services. The more recent work of floating the American line steamer *St. Paul* from the sand off Long Branch recalls the difficulty of hauling one of the great transatlantic liners off a sand-bar or mud-flat. Both the Chapman and Merritt wrecking companies, of New York, combined to float her, and the salvage money, amounting to about $100,000 (£20,000), was divided among them.

The existing ignorance concerning this great marine industry of wrecking was never more forcibly illustrated than at that time. Thousands of curiosity seekers went down to Long Branch to see the big steamer on the shoals, and it is fair to assume that about 90 per cent. of them had some simple theory by which they thought the vessel could be hauled off. The two wrecking companies received a mass of voluntary suggestions that must have been annoying, if they had not been so ridiculous in the light of experience and positive knowledge. Nothing was too absurd to be proposed, and a comical feature of all the correspondence was that a majority of the wild schemes came from inland cities, where the chances of making a practical test were so small that the reputation of the proposers could never be endangered. In view of all

DERRICKS OF THE CHAPMAN DERRICK AND WRECKING CO., NEW YORK.

these schemes proposed by individuals and newspapers, the wreckers proceeded along lines that seemed simple and tame to the public, but which long experience had taught them to be the best.

The *St. Paul* was floated, as many another good ship before her sad accident, and the wrecking companies proved again the wisdom of their conservative actions. When the news was telephoned into New York that the big ocean liner had run her nose into the sand, there was a lively race down the bay by rival wrecking companies. Usually the first company that gets on the scene has full charge of the wreck. In the case of the big American liner the amount liable for salvage was $3,000,000 (£600,000). The Chapman Wrecking Company in this instance outstripped its competitors in the race, and succeeded in getting a hawser over the stranded vessel before the others reached her side. But the steamer was too thoroughly embedded into the sand, and the value too enormous for one company to assume absolute monopoly, and there was a combination of the rival wrecking companies, and many individual owners of powerful tugs, to rescue the steamer.

As much of the heavy cargo as was practical was first removed, and then steel hawsers were stretched from the steamer to heavy kedge anchors, weighing as much as 4000 pounds, buried in the sand further out to sea. Then the powerful tugs were put into service. Sometimes donkey engines on the steamer are put into service to help the tugs in their efforts. But this method of hauling a steamer from the sand is limited by a grave danger. The strain put upon the helpless vessel may prove disastrous, and do more harm than good. In the case of the *St. Paul* advantage had to be taken of the high tides, and, by means of derricks for lifting, the tugs finally succeeded in floating the big ves-

sel. A modern wrecking steamer is a model of completeness. It is lighted throughout by electricity, and the diver has electric lights which he can carry with him down to the bottom of the sea. Lofty derricks tower above the deck, and from them dangle steel hawsers ten inches thick down to some less than an inch in diameter. Kedge anchors, chains of all sizes, and powerful donkey engines, are supplied in abundance. One of these wrecking steamers can carry a large crew of divers and workmen, with provisions and supplies enough for three months. It is rarely that they have to remain out so long, but should the emergency occur, they are prepared for it.

Ordinarily the heavy derricks are first employed for lifting vessels that need to be floated or raised from the bottom, but when they fail to budge the tremendous burden, pontoons are used. The latter are ranged along on either side of the wreck, and divers then place heavy chains under the keel, fastening the ends around the pontoons. These are first filled with water until they are sunk nearly to a level with the surface of the sea. When the chains are secured properly, the water is pumped out of the pontoons, and as they become more buoyant, they rise and bring the wreck up with them. The sunken wreck is then secured in this position, and the pontoons are once more filled with water and the operation is repeated. In time the wreck is brought up alongside of the pontoons, and repairs are made on her, the water is pumped out, and the whole fleet steams into some convenient place.

The wreckers do not always have plain sailing, however, and in the case of the steamer *Wells City*, sunk in New York harbour, in 1887, the chains were cut in two by her sharp keel just as she was brought up to the surface of the water. The whole work had to be gone over again, and although the wreckers were successful in the end, it was an expensive and aggravating job. The sinking of the ocean liner *Oregon* off Fire Island, several years ago, was even a more tantalising case than that of the *Wells City*. The divers worked energetically on the wreck for weeks and months, but noth-

LIFTING A SUBMERGED WRECK.

ing except the cargo was ever raised. Owing to the great depth of the water, and the turbulent nature of the sea in the vicinity, the divers were impeded in their work, and, in the end, the wreck had to be abandoned. The great steamer lies corroding in the sands at the bottom of the sea to-day within a mile of Fire Island lighthouse.

But where one vessel has been abandoned in recent years by the wrecking companies, a score or more have been rescued and saved from total destruction. In the same year that the *St. Paul* was hauled off the shoals of Long Branch, the Long Island Sound steamer *Puritan* was successfully floated from a dangerous mooring off the New England coast. In this case the amount involved for salvage was at least $2,000,000 (£400,000).

The real history of modern wrecking begins in 1830, when the first organisation was formed. In 1836 the emigrant ships *Bristol* and *Mexico* were wrecked on the Long Island coast, carrying down with them nearly all on board. These fearful disasters emphasised the necessity of better wrecking facilities, and new wrecking companies soon entered the field. Since then their efforts have been invariably successful. Very few losses are to be set against them, and even these must be viewed with leniency considering the conditions under which they happened.

A TYPE OF AMERICAN NAVAL ARCHITECTURE. THE FALL RIVER LINE STEAMER "PRISCILLA" LEAVING THE PORT OF NEW YORK.

THE FUTURE OF AMERICAN SHIPBUILDING.

From An American Point of View.

By Lewis Nixon.

THAT a large amount of shipbuilding must be done in the United States, even under present conditions, to meet the demands of the coasting and river trades, is undoubted, but we must turn our attention to shipbuilding in a broader sense and determine whether we are to enter the field as builders and owners of oversea carriers.

The question as to whether we can build ships equal to those built by other nations admits of no discussion. Vessels already built speak for themselves. In the matter of the raw material we are in a better position than any other nation, and the rebuilding of our navy has developed the various contributory industries to the point that the material used in our vessels is certainly equal, if not superior, to that produced elsewhere.

The demands of the coasting and lake trade built up a number of shipyards that were well managed and efficient, and which, under the stimulus of the shipbuilding programme lately inaugurated by the general government, were able to instantly respond to the most exacting demands.

The character of the American workman, too, adds greatly to the production of a shipbuilding element in accord with the management of the industry. The capital of the labouring man is one that gives an immediate cash return, and the

THE UNITED STATES BATTLE SHIP "INDIANA." TWIN SCREWS. LENGTH, 348 FEET. DISPLACEMENT, 10,000 TONS. I. H. P., 9000. SPEED, 15½ KNOTS.

chances of being out of employment in case his particular trade is an established industry are far more than offset by the risks to capital invested which often loses, not only interest, but principal.

The employee sells his labor for cash at current rates. The employer, owing to competition and various conditions over which he has no control, may find it necessary to reduce expenses, and while it is not possible for employee and employer to see matters in the same light, the chances of clashing are far less in the United States than in England, for example.

The men to whom the labour elements look for advice are in this country more really interested in the welfare of the labouring class and are disposed to make more effort to keep men at work than to cause them to strike. This is, to a certain extent, due to the much better condition of labour, class for class, here than in England. Our people live in better houses, take better care of their children and exhibit a lively interest in political affairs, especially such as affect their condition. For this reason a protracted period of idleness is of much more serious moment to them, and their insight into matters of costs and responsibilities of work, as an outcome of a generally intelligent and thoughtful condition, enables them to see that a change is not always evidence of a grinding down of labour, but possibly one that will work a benefit by tiding over a business which might otherwise have to close up altogether.

In England the shipyards are entirely in the hands of organisations, and work upon a great vessel has been stopped for months because the men could not decide whether carpenters or joiners should do a certain class of work. Such a thing would not happen in this country. When labourers from other countries come here, they seem to imbibe very shortly the ideas and methods of those already at work and fall into their habits very quickly.

So, while for a long time the wages in this country will be higher than those abroad, the productivity of a man-day will gradually increase as compared with that in England, for example.

The raw material and the labour, then, being such as to give a promising outlook for the future, it may be asked, what is lacking? The answer is, a demand for American ships for oversea traffic.

The demand for ships will increase most rapidly, just as the demand for express and freight service increases, as neighbouring communities become more populous and productive.

The United States will produce and demand vast quantities of sea freight, but it remains for those charged with the formation of treaties and laws to say whether any of the traffic tolls are to come to us or to be earned, as now, by other nations. The American ship to-day is at a disadvantage as compared with that of any other nation grasping at the money paid for sea freight.

It is believed by many, and hoped for by all, that the United States are destined to be a great manufacturing nation. No nation can be a great manufacturing nation unless it produces more than it actually needs for its own consumption. To compete with other nations whose trade is already established we must be able to produce a superior article at the same price, or one equal in value at a less price at the spot where it is sold. We shall eventually do this even though we carry the products in the vessels of some other nation. But think of the constant drain from us to that other nation in the shape of traffic tolls, brokerage, banking charges, insurance, and the various profits of handling! Compare two stalls in a market, one owning its delivery wagon, and one paying others to attend to the delivery!

It is said that ship-owning does not pay. The little island of Great Britain controls the finances of the world because the ownership of the express and freight wagons of the sea is hers,—and all the world pays tribute.

We shall produce, in years to come, a vast quantity of the world's freights and shall demand of other nations a like amount for our own needs. Under ex-

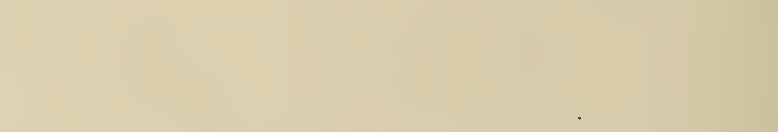
isting conditions we cannot afford to own the vessels to carry even our present share of the world's cargoes. We cannot progress under such conditions, and I am enough of an optimist to believe that the people of the United States will insist upon a broader policy than the one under which our foreign commerce is stifling.

If other nations have planted thousands in order to reap millions in the way of direct encouragement of ship owning, we must do the same. The means of doing this are questions of national statecraft and legislation, but to be beneficial they must rise above parties, and become simply American.

The tariff question, which has done so much to check the growth of industry, must soon settle itself. The farce which has been played so many years will end by bringing out the moral that we must have a revenue equal to our expenditures, and that the expenditures, even with rigid economy, must increase as the nation increases. The two great political parties in the United States have now got so close together on the tariff that our methods of raising revenue may be said to be settled till the time comes when we shall produce all we need of such articles as can be made or raised in this country. The money question must, likewise, settle itself in a few years, and that by the influence of the world at large, for it is with money as a medium of exchange with other nations, and not among ourselves, that we are most concerned. The question of money, be it gold or silver, is not a local issue.

The great question of policy most affecting the United States is that of our oversea commerce. It will give rise to differences of opinion, but we must note that our rivals do not allow politics to play a part in the methods adopted by them, and we must note, too, that the great commercial nations jealously guard and foster their ship-owning.

We must progress seaward or stand still. We shall not do the latter, and when a policy is inaugurated and persisted in that will make ship-owning as profitable to Americans as to foreigners, then will the American shipyard rise to the occasion, and shipbuilding become our greatest industry.



CHARGING A BLOCK OF BEE-HIVE COKE OVENS.

BY-PRODUCT SYSTEMS OF COKE MAKING.

By William Gilbert Irwin.

TO-DAY the great coke industry is undergoing a revolution, long foreshadowed and dictated by economic conditions and progressive engineering. Already the old-fashioned bee-hive oven has been eliminated from the coke fields of England, Germany, France and Belgium, and although, at first, seemingly reluctant to follow in the wake of European coke makers, those of America have come to see the inestimable value of the by-product systems and are accordingly adopting them so that they, likewise, may reap profits by saving and utilising those products of which no consideration whatever is taken by the old coking system.

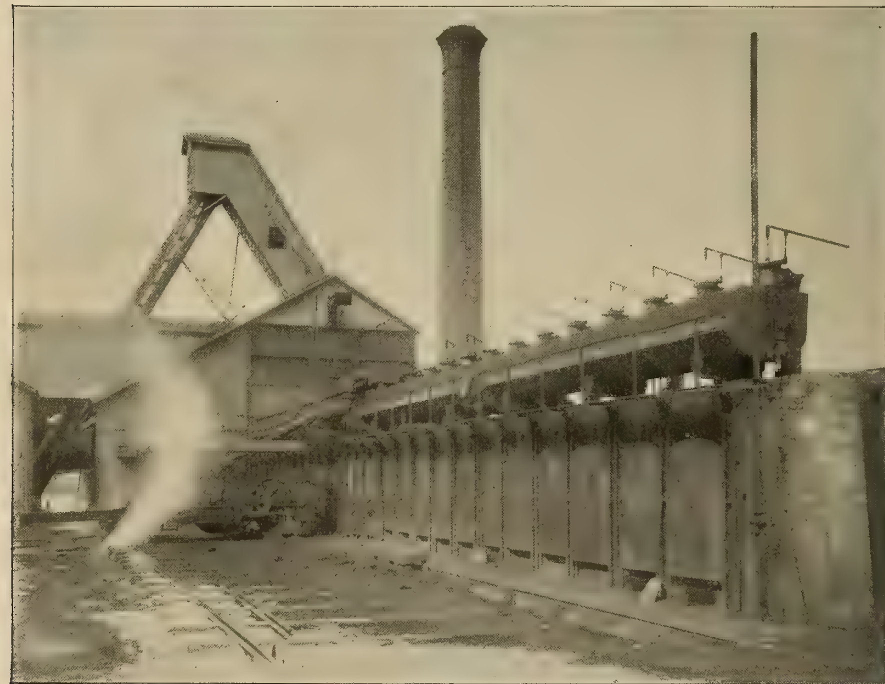
As far back as 1768 tar was produced in a by-product oven by chemical processes at Fischbach, in the coal fields of Saarbrücken, in the German Rhineland province. As early as 1848 the coke makers of England, Germany, France and Belgium had begun systematic experiments on the new processes, and by 1863 a very efficient by-product plant was in operation at St. Etienne, in France. The chief improvements in the by-product ovens have been in the scrubbers and condensers.

Great Britain was not so ready as was Continental Europe to adopt the by-product systems, and it is only recently that her coke makers abandoned the old bee-hive oven system and adopted the more modern ideas. In 1882 Sir Lowthian Bell made experiments and issued a work in which he claimed that the by-product oven coke was at least ten per

cent. inferior to the bee-hive oven product. This was an important consideration to coke buyers, and, had the contention been borne out by experiment, the loss would have rendered the adoption of the ovens out of the question. But soon Sir Burnett Samuelson disputed these conclusions, and by experiments showed that the product of the new ovens was equal in quality to that of the bee-hive ovens when produced from the same coal and under identical conditions, and that the quantity of the product of the new ovens was greater.

Still there remained some doubt as to the value of the product of the new ovens for furnace purposes, and this caused delay in the general introduction of the new systems into Great Britain. But a dozen years of experiment and successful operation have removed all uncertainty as to the quality of the by-product oven coke which, in comparison with the bee-hive oven coke, has many times been proven equal, and superior, to it. The early importation of by-product oven coke into England from Belgium and Germany clearly demonstrated its value and hastened the general introduction of the systems. Having thus conquered the Old World, the new coking ideas turned to progressive America to seek entrée into her great coke and coal fields.

The bee-hive oven takes its name from its shape. It is usually twelve feet in diameter and from seven to eight feet high, and has two openings, one in the top through which the oven is charged and the burning gases and waste products of combustion are allowed to escape into the air, and a door in front through which air is admitted to aid in combustion and through which the coke is drawn. In these ovens it requires about forty-eight hours to coke a charge of coal, and in some cases a seventy-two-hour coke is made.



A PLANT OF 25 BY-PRODUCT OVENS AT SYRACUSE, N. Y., U. S. A., INSTALLED BY THE SEMET-SOLVAY CO., OF SYRACUSE.

The by-product oven, regardless of

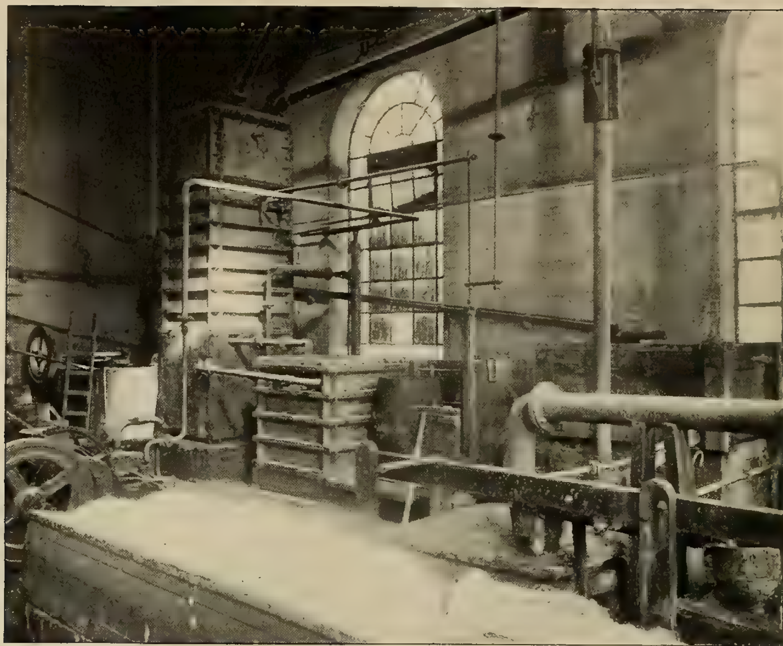
AT THE TOP OF A BANK OF SEMET-SOLVAY RETORT COKE OVENS, SHOWING CHARGING TUBS.

the pattern, is a closed one, no air being admitted while the coal is being coked. The exclusion of air from the retort oven does away with combustion in the coking chamber, and the heat necessary for coking comes from the combustion of air and gas in the flues, side walls and bottom of the oven. The oven itself is a long, narrow chamber, varying from 18 to 30 inches in width, from 6 to 7 feet in height, and from 25 to 33 feet in length. It is charged through a number of openings in the top, the charge being from five to eight tons of coal. In these ovens the coking process is completed in from eighteen to thirty hours.

In the bee-hive oven the mass of coal, as it fuses into coke, swells and rises. If, on quenching, it falls back to its original bulk, it makes a hard coke; if not, a soft coke is the result. In the bee-hive oven there is no way of obtaining a uniform coke nor does the oven make any provision for the physical improvement of the coke, and so far as the quality of the product depends upon the oven, it might as well be coked in an open rick upon the ground, for the bee-hive oven is to-day as primitive a structure as when first devised.

But, notwithstanding all these disparaging facts, this primitive coking system still predominates in the Connellsville coke region in Pennsylvania and in other coke regions of the United States, and, singular to say, the system has been eminently successful. But the coal of these regions is well adapted to coking. In fact, ovens are not necessary in the coking of the coals, for they have been successfully coked in open ricks on the ground. But the bee-hive ovens have also been tried in coal regions where a harder coal is obtained, and there they have invariably resulted in failure, helping to demonstrate that they are unsuited for the coking of any but a natural coking coal.

For the retort oven systems it is laimed that they will, to a large extent, cdapt themselves to the different coals,



THE SULPHATE OF AMMONIA HOUSE AT THE BRYMBO STEEL CO.'S FURNACES, AT BRYMBO, WALES.

and in many cases a good quality of coke can be produced by these systems where the bee-hive oven system would result in utter failure. In the by-product oven method there is, too, some system in the coking process and definite results can be obtained. When the coking coal swells in the narrow retort chambers, it cannot expand. It is compressed vertically as well as laterally, and the result is a uniform coke whose hardness varies with the charge of coal in the oven. Just as common coke is superior to anthracite coal for furnace purposes, so is retort oven coke superior to ordinary oven coke.

Anthracite coal, at one time a bituminous or soft coal, is really a coke produced by nature. The volatile matter contained in it was driven out by the mighty forces of nature during the earth's chaotic period. This coal is much freer from volatile matter than is ordinary coke, and contains more carbon, both of which facts tend to enhance its fuel value; but overbalancing these is its density, caused by the immense pressure during its plastic condition.

In the ordinary bee-hive oven coke the porosity of the product is great, but toughness and hardness,—very essential qualities of a perfect fuel,—are lacking. The porosity of the coke is too great to combine in it these essentials. On the other hand, the cell space of the by-product oven coke, while equally as great as that of the bee-hive oven product, is more proportionally distributed, and, in addition to being richer in carbon than is the bee-hive oven coke, toughness and hardness are so combined as to make this coke a nearer approach to an ideal furnace fuel than has yet been produced.

In matters pertaining to the relative value of the bee-hive oven coke and that of the retort oven system, it is not necessary to be theoretical. The facts are before us. The composition of all coals varies greatly as does the coke produced from them by either the bee-hive or by-product oven systems. In good coking coal the ash varies from 4½ to 7½ per cent.; the volatile mat-

ter, from 27.90 to 33.60 per cent.; the fixed carbon, from 58.10 to 65.36 per cent.; and sulphur, from 1.00 to 1.92 per cent. The following analysis of Connellsville coking coal is regarded as a standard one for coking coal:—

Water	1.30
Volatile matter	29.812
Fixed carbon	60.420
Sulphur	0.629
Ash	7.949

Bee-hive oven coke analyses as follows:—

Water	0.032 to 0.490
Volatile matter	0.460 to 1.296
Fixed carbon	89.560 to 89.147
Sulphur	0.821 to 0.840
Ash	9.113 to 9.523

The above is the results obtained from the best coking coal by the bee-hive oven process. There is not obtainable any analysis of coke produced by the retort oven system from coal of such good quality. The analysis of coke produced by the new system from Connellsville coking coal of medium quality shows the following results:—

Water	0.28
Volatile matter	1.15
Fixed carbon	86.67
Sulphur	0.67
Ash	11.90

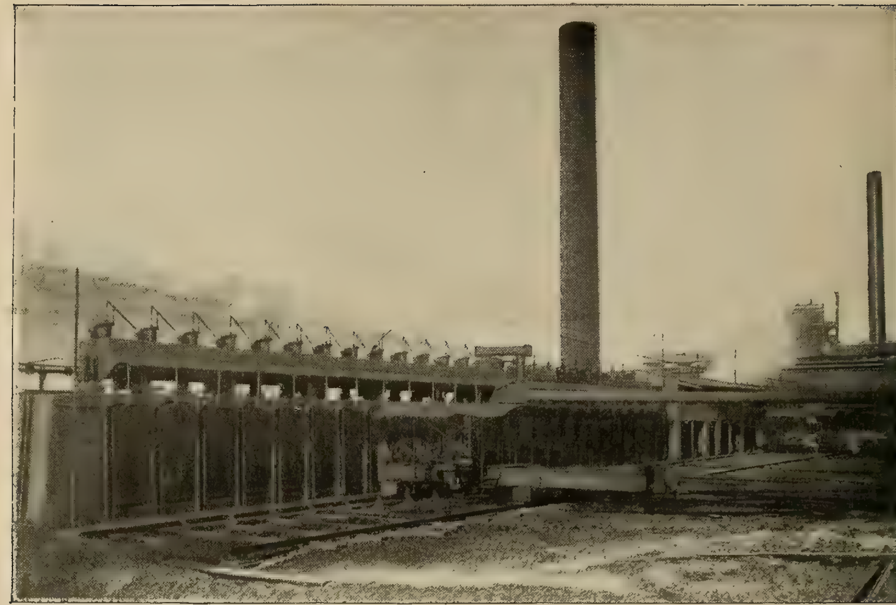
impurities of coke are sulphur, phosphorous and the excess of ash over the amount required for structural strength which, in furnace coke, must necessarily be great. In the retort oven coke the water and the sulphur, which are so injurious to all metals, are in all cases greatly reduced and late experiments show that these will soon be rendered infinitesimal in quantity.

The difference in the quantity of the coke produced by the bee-hive and the by-product systems is from 10 to 13 per cent. in favour of the by-product system. With this conclusive evidence that the by-product oven coke suffers none in comparison with the bee-hive oven product, let us now consider the utilisation of the by-products, the profits of which are all clear gain to the by-product coke plant operator.

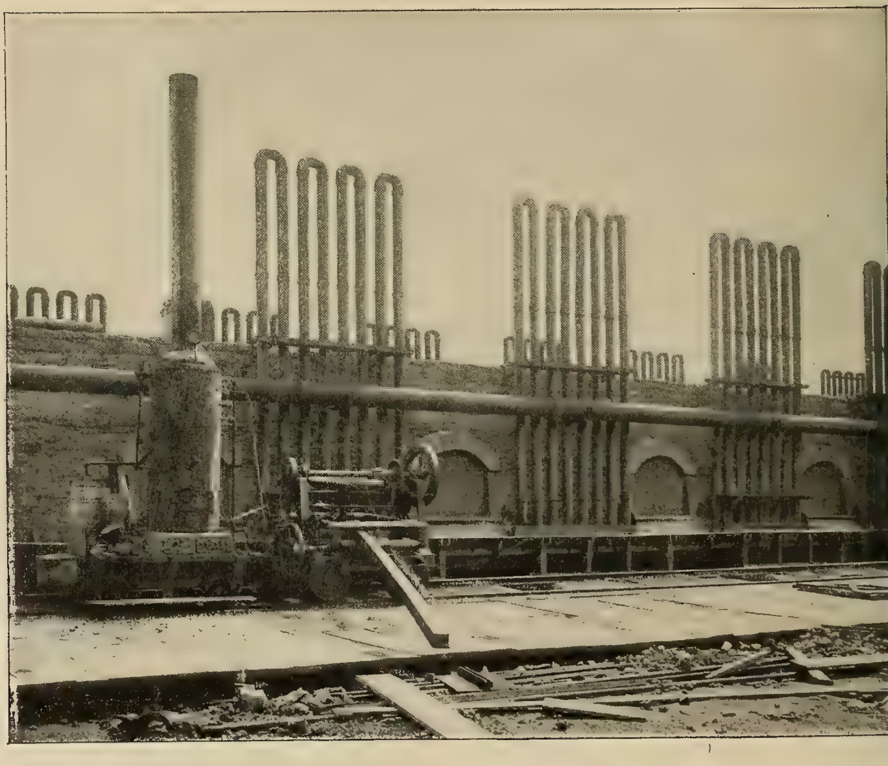
A thorough analysis shows that the primary products of bituminous coal are coke, fuel gas, ammonia and tar; and that the secondary products are illuminating gas, benzol, pitch, xylol, tutuol, phenol, naphthalene, anthracene, creosote and parydine. With the exception

A BATCH OF COKE AT THE BRYMBO STEEL CO.'S FURNACES JUST AFTER PUSHING OUT.

Beside the improvement in the physical quality of the retort oven coke there is also a like improvement in chemical composition. The three characteristic of coke, all these constituents are lost by the bee-hive system. To-day the great coke regions in the United States are marked by flame and fire and soot.



SEMET-SOLVAY RETORT COKE OVENS OF THE DUNBAR FURNACE CO. AT DUNBAR, PA., U. S. A.



ENGLISH BEE-HIVE BY-PRODUCT OVENS OF THE LATROBE COKE AND COAL CO., LATROBE, PA., U. S. A

Everywhere the ovens shoot out their tongues of living fire, and above them rise great clouds of smoke.

In the United States there are mined annually upward of 20,000,000 tons of coking coal, from which are produced more than 15,000,000 tons of coke. The late Joseph D. Weeks, United States Government expert on coke and coal, estimated that the combined value of the products which the by-product oven systems, now being introduced, propose to utilise, cannot be less than 66⅔ cents per ton of coke produced. The annual loss to American coke makers, even at this low estimate, is in the aggregate, enormous.

The chief of the by-products utilised by the by-product oven systems is ammonia. Hitherto the sole source of supply of ammonia in the United States was in the illuminating gas plants, but the use of electricity and of water gas has decreased the production of the article while the demand for it has been on the increase. Ammonia has many uses. It is an essential material in ice manufacturing, in electrical batteries, in chemical manufactories, and in the manufacture of fertilisers it is substituted for nitrate of soda. The yield of ammonia from regular coking coal is about 20 pounds per ton of coke produced, and at the minimum value of \$20 (£4) per ton, this product alone would be worth 20 cents (10d.) for each ton of coke.

Two kinds of gas are obtained from coal by means of the retort coke oven system. These are illuminating gas and manufacturing or fuel gas. The latter makes a very good substitute for natural gas. The production of illuminating gas in the retort oven involves a change in the operation of the oven so that ordinarily produced gas, with the recuperation of both gas and air, may be burned in the flues instead of the rich coke oven gas. It has been estimated that for each ton of coke produced upward of 8000 cubic feet of gas are given off, and the entire product yielded annually in the United States by the coking of coal, allowing one-half of the product to be consumed in the coking process, is upward of 60,000,000,000 cubic feet, or but little less than one-fourth of the annual natural gas production during the height of that excitement.

By-product oven tar is superior to the tar which comes from the gas works. It contains less pitch. The yield for

THE PUSHER SIDE OF A BANK OF SEMET-SOLVAY OVENS AT DURHAM, ENGLAND.

each ton of coke varies from 40 to 100 pounds, according to the amount of volatile matter contained in the coal. It has a fuel value equivalent to \$5 (£1) per ton, or that obtained by coking a ton of coal is worth from 10 to 25 cents (5d to 1sh.). As a roofing and paving material this tar has a value of about \$8 (£1 12sh.) per ton.

As a material for the manufacture of fuel briquettes, coke oven tar stands pre-eminent. In addition to the above uses, this tar, after passing through the complex processes of modern chemistry,

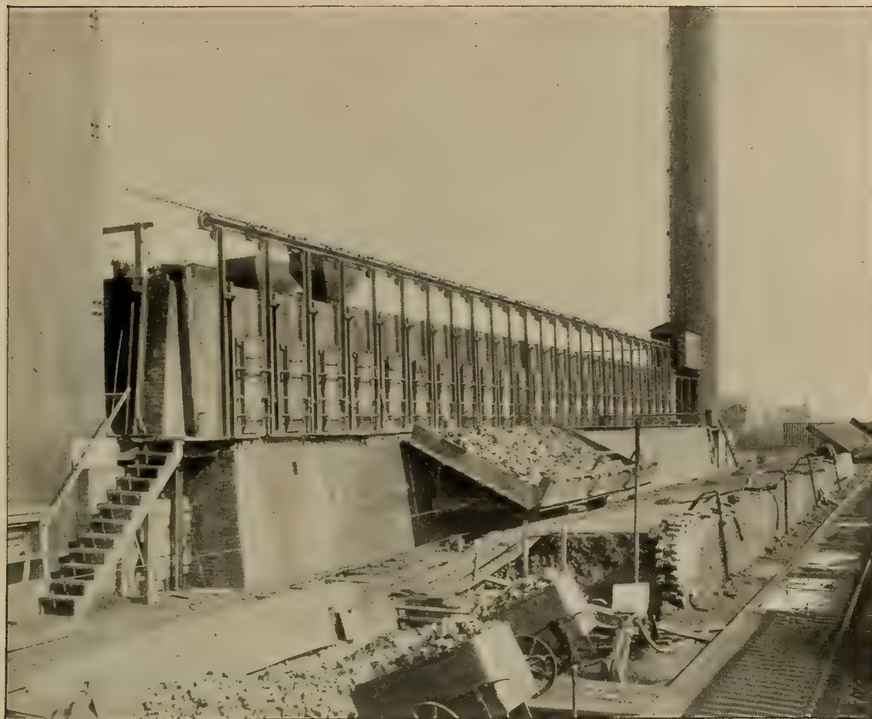
comes to us in form of aniline dyes, saccharine, benzol and other products. As yet America has not ventured far in this field, which now seems to be without limits.

Of the retort oven systems with by-product recovery apparatus now seeking introduction into the United States, there are two general types. The one, chiefly represented by the Otto Hoffman oven, has vertical flues and regenerative firing; and the other is represented by the Semet-Solvay oven, with horizontal flues and continuous recuperation of heat. Under the exploitation of one of the leading firebrick manufacturers of Germany the Otto Hoffman system has, during the last fifteen years, attained a wide development in Europe. The erroneous principle of applying the expensive system of the Siemens regenerator to a fuel operation requiring only moderate heat has long been manifest, and this error has been demonstrated by the success of the simpler method of continuous recuperation as used by the Semet-Solvay system.

A close study of the opposing principles involved in these two retort oven systems evinces a decided superiority in favour of Semet-Solvay system. The ovens are not more than eight feet high and in the vertical flue system the heat of distillation must do its work in that short space and in a direction where the natural flow of the gas is most rapid. In this system the highest heat will be at the top of the vertical flues, while it should naturally be at the bottom, in order to insure perfect distillation.

COKE CRUSHER OF THE H. C. FRICK COKE CO., IN THE CONNELLSVILLE REGION, WESTERN PENNSYLVANIA.

With horizontal flues making three turns along the sides of the oven and one underneath its sole, the gases pass through a circuit of 120 feet and the opportunity for imparting heat to the interior of the oven is simplified and rendered more efficient. In this system the greatest heat is easily regulated at the lower part of the oven, and the available heat of the fuel is more thor-

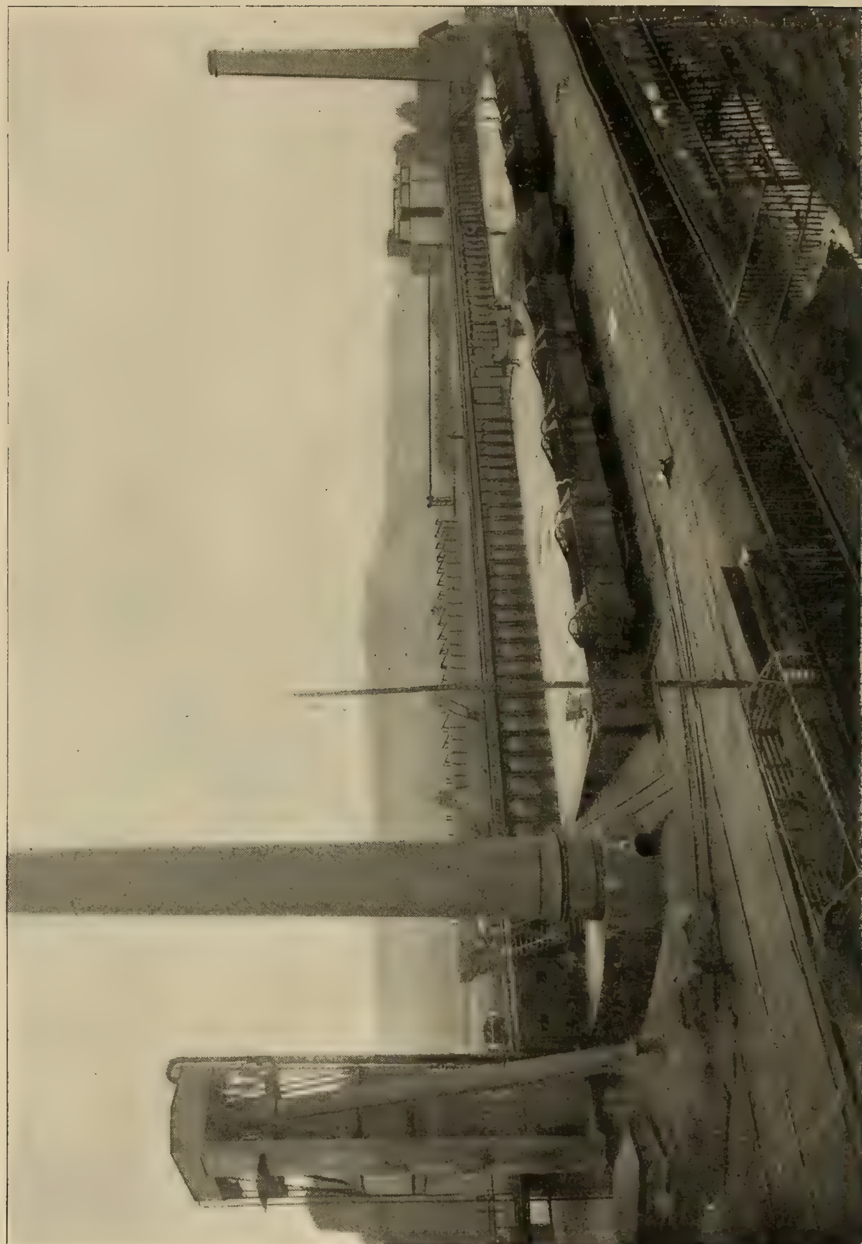


THE DISCHARGE SIDE OF A SET OF SEMET-SOLVAY RETORT COKE OVENS AT SHARON, PA.

oughly exhausted. This also explains the superiority of the recuperative system over the regenerative.

The grafting of the retort oven systems upon the American coke industry has had many infantile vicissitudes and the new coking systems are yet not far removed from their infancy. All the early efforts resulted in failure. The first successful by-product oven plant erected in the United States was a plant of twelve ovens of the Semet-Solvay type, which was built at Syracuse, N. Y., in 1891. This plant was put in operation on January 1, 1892, and since that time has been in uninterrupted operation. At present this plant consists of thirty ovens. In the ovens of this plant nearly all kinds of coking coal have been used, and the increase of the yield over the bee-hive oven runs from 15 to 40 per cent. In numerous tests the coke produced at this plant has proven superior to the best bee-hive oven coke. On this point conclusive figures are plentiful. Among the experts of the United States who have conducted tests are Charles H. Foote, of the Illinois Steel Company; John H. Fulton, of the Johnston Iron Company; the late Jos D. Weeks, coke and coal expert for the U. S. Geological Survey, and R. M. Atwater, of Syracuse, N. Y. J. H. Darby, an English expert in the employ of the Brymbo Steel Works, in Wales, has also made extensive experiments and has thoroughly tested the value of the new coke as a furnace fuel.

The successful furnace tests of the Semet-Solvay retort oven coke have been productive of good results. At Dunbar, in the Connellsville coke regions of Southwestern Pennsylvania, the system has been adopted, and there the Dunbar Furnace Company has now in operation a plant of fifty of these ovens. At Sharon, Pa., a plant of thirty such ovens is now turning out an excellent quality of coke, and at other places



SEMET SOLVAY RETORT OVENS AT THE STEEL WORKS OF THE JOHN COCKERILL COMPANY, SERAING, BELGIUM.

FINISHED COKE AS PUSHED OUT OF THE OVENS AT THE CARLTON IRON CO.'S FURNACES, AT DURHAM, ENGLAND.

ovens of the same pattern are now in course of erection.

The by-products utilised by the Solvay system are ammonia, tar, and gas. Among the advantages claimed for the system are simplicity, low cost of construction, rapid gasification on account of the thin walls, recuperation of waste heat, and facilities for repairs. The cost of the ovens will, of course, vary somewhat with the region in which they are built. Dr. Spannagel, director of the Phœnix Works at Ruhrort, Germany, estimates the cost of a Solvay oven, with by-product recovery apparatus, at $1624 (about £324). The cost of an oven of the same type in America is somewhat greater, but even at twice this cost the ovens are cheap when compared with the bee-hive ovens.

There is produced annually in an oven of the Semet-Solvay type four times as much coke as is produced in a bee-hive oven, and the value of this coke, added to that of the utilised by-products, is at least seven times the value of the coke produced in an ordinary bee-hive oven. These facts in favour of the retort oven system, as represented by the Semet-Solvay oven, point to the early triumph of the retort over the wasteful bee-hive oven system.

The Otto-Hoffman system, of German origin, is much in favour with European coke makers. The American rights for it are controlled by the United Coke and Gas Company of Philadelphia. The Cambria Iron Company have in operation at Johnstown, Pa., a plant of sixty of these ovens and at other places plants are being erected. The two great differences between the Otto-Hoffman and the Semet-Solvay retort ovens have already been mentioned.

Another by-product system which is at present represented in America by a single plant is the English Bee-Hive By-Product System. A plant of thirty

of these ovens has been erected by the Latrobe Coke and Coal Company at Latrobe, Pa., and this plant was put in operation one year ago. The ovens of the plant are somewhat larger than the regular bee-hive ovens, but the coking chamber is about the same size and the same charge is used.

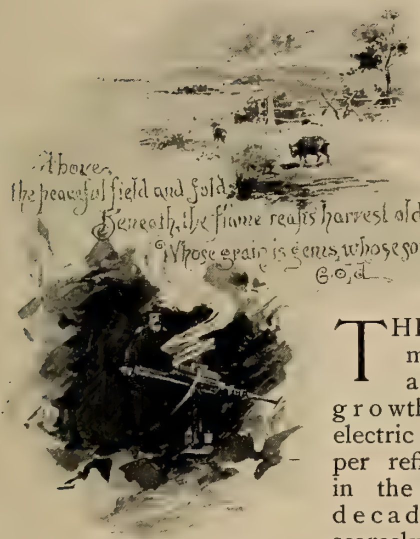
For twenty-four hours the ovens are kept closed and during this time the by-products are extracted. The gases are first carried from the coking chamber into a condenser and from there through vertical ventilating flues and thence to tanks where the ammonia is extracted. From these tanks the gas is conducted into reservoirs connected with pipes, and it is either used in heating the boilers which run the mine machinery or is pumped away and used for other purposes. When the by-products have been obtained, the ovens are opened and air is admitted during the remaining twelve hours of the coking process. The coke is drawn from these ovens by a coke-drawing machine, while in the other retort oven systems a pusher is employed. This machine coke drawing will also work a revolution in the coke industry.

While these retort oven systems have been struggling for recognition in the United States American inventive genius has not lain dormant The early introduction of these systems set the minds of American coke makers to work just as their subsequent introduction into England had fired the minds of the coke makers of that country, and here as there, a new system has been evolved.

The new American retort oven system was designed by Mr. Laughlin, manager of the Laughlin Furnace Company of Pittsburg, Pa., after a critical examination of foreign retort oven systems. An experimental plant of twenty ovens has been erected, but as yet the system has not been perfected. Mr. Laughlin's idea is to coke the coal in perfectly air-tight chambers. By the utilisation of the liberated gas and through a system of checkers beneath the coking chamber, it is hoped that a coke free from all chemical agents acting deleteriously on iron, will be produced. The by-product arrangement for the system has not yet been perfected.

ELECTRIC COPPER REFINING IN THE UNITED STATES.

By Titus Ulke, E. M.



THE remarkable growth of electric copper refining in the last decade is scarcely paralleled in the history of any other industry. About thirty years ago, James Elkington, an English silver plater, invented the commercial electrolytic method of refining crude copper, and founded the first plant using this process, at Pembrey, Wales. The works established by the father of modern copper refining are to-day in successful operation, due chiefly to the remarkable fact that both Elkington's process and apparatus were well conceived and needed but little improvement to bring them up to present standards. However, it was not until the last decade, when the spread of electric lighting led to an enormous demand for pure copper, that the great importance of Elkington's invention was fully realised.

In 1879 an experimental plant for refining copper by electrolysis was operated at Phœnixville, Pa., but the first commercial refinery in the United States was built by Edward Balbach, at Newark, N. J., early in the eighties. The refineries at Baltimore, Md., and at Anaconda and Great Falls, Mont., were not started until 1887, 1891 and 1892, respectively. Ten years ago, the Balbach and the Bridgeport, Conn., works were the only large electrolytic plants in America, and their total output was less than 24 tons daily. Yet to-day there are in operation eleven electrolytic refineries, producing the large quantity of 342 tons daily, or about one hundred and twenty-four thousand tons of copper annually, besides over fourteen million ounces of silver and sixty-eight thousand ounces of gold. Thus, considerably over one-half of all the copper produced in the United States is now refined in the electrolytic bath, or one-third of the production of the world.

Still more astonishing is a comparison of the cost of producing electrolytic from crude copper five years ago with the cost to-day. Then it was about $20 (£4) per ton, although refiners charged $40 and allowed only 92½ per cent. on the commercial value of the silver, which is always found in the crude Bessemer or blister copper. Now, the cost of refining 98 per cent. Bessemer copper at several of the large works has actually been lowered to $8 (£1 12s.) per ton, as against $13 (£2 12s.),—notwithstanding lower wages,—in Europe, and contracts can be closed for $10. The cause of the great reduction in the cost of refining is economy in utilising power and in handling material.

Electrolytic refining consists essentially in removing the impurities and precious metals from the crude copper and depositing copper, relatively free from these elements, electrically. There are only two system of electrolysis now in use, which differ chiefly in the mode of arranging the electrodes. They are known as the multiple and the series

THE ELECTROLYTIC REFINERY OF THE ANACONDA COPPER MINING CO., ANACONDA, MONT. CAPACITY, 50 TONS. TANK SERVICE BY ELECTRIC TRAVELING CRANE.

processes, the former being more commonly used than the latter and of greater relative value.

At a typical modern copper refinery of 30 tons daily capacity and arranged according to the multiple system, the crude copper is received in bars or cakes obtained by the usual process of copper ore smelting and concentration. After being drilled and sampled, to determine the quantity of copper, silver and gold it contains, the metal is heated in a reverberatory furnace, and cast into anodes for the electrolytic bath.

The anodes are 2 feet 6 inches long, 2 feet wide, 3 feet 2 inches across the lugs by which they are supported, and 1¼ inches thick. By means of tackle running on an overhead rail, the anodes are placed in the depositing tanks, so as to alternate with the cathodes, which are pure copper sheets 0.04 inches thick. The anode and cathode plates are separated by about 1¼ inches. Each tank when "loaded" contains 22 anodes and 23 cathodes.

The tanks are arranged in terraces, with the object of facilitating circulation of the electrolyte. There is a difference of level of about 2 inches between each row of tanks, and an overflow pipe of the necessary diameter keeps up a sufficient circulation to maintain the electrolyte in proper condition, there being a constant supply of new fluid to replace that drawn off. The tanks, which number 312 in all, are of 2-inch pitch pine, coated with paint, each being 10 feet long, 3 feet deep and 2 feet 6 inches wide. They are arranged in pairs, placed in twelve rows of thirteen double tanks each.

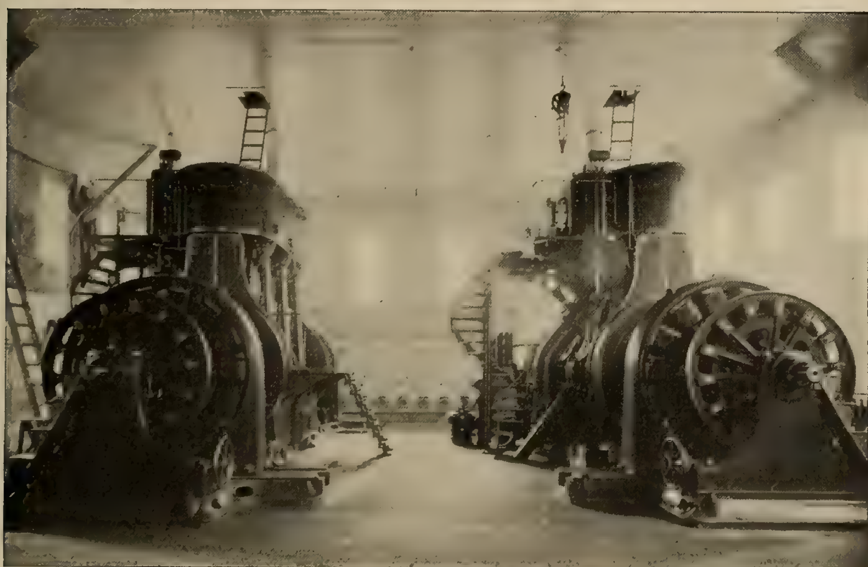
The electrolyte, as prepared for the bath, has in solution, by weight, 16 per cent. of bluestone and 5 per cent. of free sulphuric acid. Samples from the tanks are tested daily, in order that any

deficiency in the water, acid or bluestone contents of the electrolyte may be supplied in time to prevent any trouble. All of the 312 tanks are in series, and the electrodes or plates are in multiple. On the outer side of each tank is a copper bar, 1¾ inch square in cross section, and on the inner side a wooden bar, which together form the supports for the anodes and cathodes; the two outer bars of each pair of tanks are the + and — conductors. The top edges of the cathodes are bent over ½-inch square copper cross rods, from which the cathodes hang, while the anodes are supported by their own lugs.

The distribution of the current is as follows:—Under one end of each cathode is placed a square porcelain block, insulating every cathode from the positive conductor, so that the current entering a tank through its 22 anodes in multiple, will proceed through the bath to the adjacent cathodes. From these it then passes by means of copper connectors, to the anodes, insulated from the negative conductor of the second bath, or tank, built against the first. The connectors are plates 6 inches long, 2½ inches wide and ⅛ inch thick, supported on wooden strips and connecting the end of a cathode in one tank with the anode in the adjacent tank, hanging in the same vertical plane.

Continuing through the second bath, the current enters the cathodes therein, passes to the extreme conductor, and enters the next pair of tanks, in which its course is the same as that just described. Thus the tanks of each pair are in series, the same as the adjacent tanks of a row, while the plates are all in multiple.

The average electric current is about 10 ampères per square foot (counting both sides of the anode plate), and it requires about 24 days of 24 hours to electrolytically transfer the copper of the anode to the cathode plate, the weight of the former being about 275 pounds. The flow of current employed varies with the richness of the anode in precious metals and with its contents in arsenic and other impurities. If large quantities of these are present, a high current density would carry part of the silver and arsenic to the copper, and thus reduce its purity and the electric conductivity.



THE DYNAMO ROOM OF THE ANACONDA REFINERY.

With very pure crude copper currents

as high as 15 and even 20 ampères may be used. The voltage, of course, depends only upon the ohmic resistance of the electrolyte, conductors and plates. It averages between 3-10 and 4-10 of a volt per tank. With 308 tanks (four tanks are always out of circuit, having slime removed and being otherwise cleaned), the volt meter at the switchboard registers from 117 to 120 volts with 1500 ampères.

The deposited sheets of pure copper are either sold as commercial cathodes or they are melted in reverberatories and cast in wire bar moulds in suitable shapes for wire drawing.

Besides the above tanks for the commercial electrolysis, there is a separate system of thirty tanks in which the cathode plates are manufactured as follows:—Rolled copper sheets 0.1 inch thick, placed in a frame of three wooden strips, are oiled and covered with graphite on both sides in order to prevent the copper which is subsequently deposited on them from sticking. Thus prepared, they are suspended in the cathode tanks between commercial anodes and receive the cathode deposit, which is permitted to become 0.04 inch thick. The shells are then stripped from the plates and are ready for use as cathodes in the commercial tanks.

In the above described refinery, the copper treated is usually rich in precious metals, carrying at times 600 ounces of silver and four ounces of gold to the ton of copper. If the current is kept at the proper density, all of these metals, together with impurities like lead and antimony, are deposited in the bottom of the tanks in the form of a black slime or mud.

These slimes are carefully gathered and screened from anode scrap through a perforated sheet copper screen which is suspended in a tank in which the slimes are "boiled"—*i.e.*, stirred up with acid so as to expose them to air as much as possible. The boiling tank is a lead-lined vat, filled to a height reaching a little above the bottom of the screen, with hot dilute sulphuric acid (1 of acid to 4 of water) and provided with a perforated lead coil, communicating with a Korting injector. The injector supplies both hot air and steam to oxidise and dissolve the impurities in the slimes and thus to concentrate the silver and gold during the boiling.

The slimes constitute about 4 per cent. of the total weight of the anode copper refined, and after screening average 15 per cent. to 30 per cent. of metallic copper, 45 per cent. to 50 per cent. silver, less than 1 per cent. gold, and from 20 per cent. to 35 per cent. of impurities, such as arsenic, antimony, tellurium, bismuth and lead, all in a more or less oxidised condition. Although the boiling is not continued longer than eight or nine hours, practically all the arsenic, antimony and other impurities are dissolved, and are then removed by siphoning off the solution and wash water from the boiled silver mud or slimes. The latter are then dried on iron pans in a hot air chamber, and are then sent to the lead refinery.

Only forty labourers, at $1.10 (about 4s. 5d.) per day, are employed in the copper refinery. Even this is a larger number than would otherwise be required, because of the need of washing the anodes. This necessity arises from the fact that the anodes run unusually high in silver—*i.e.*, at least 150 ounces per ton, and that they must be removed from the tank, and the adhering film of silver and other impurities washed down, in order to prevent polarisation of the anodes and reduction of their effective area.

The 30-ton refinery described above is modern in every respect and occupies a floor space of about 200 feet square. Under a single roof of several bays it covers the engine and dynamo plant, the cathode and commercial tank system, and the crystallising plant.

A crystallising plant, although bulky and cumbersome, is, at present, a necessary adjunct to every copper refinery, as no practical means has yet been devised for replacing it. Its object is the recovery of copper in the shape of bluestone.

When the electrolyte, through long use in circulation, has dissolved such an

amount of arsenic, antimony or iron that its continued use would cause the deposition of these metals or of their combinations on the cathodes—*i.e.*, the production of a copper unfit for electrical purposes, the electrolyte must either be purified, or else discarded, after its copper has been taken out. The latter course is generally adopted, as the three methods of purifying the electrolyte thus far suggested, (1) filtration through a bed of copper oxide, (2) boiling with metastannic acid, (3) oxidation with jets of air, have not given anything like satisfaction.

A method of purification believed to be in use at Anaconda, consists in repeatedly passing the impure electrolyte through a filter of oxidised granulated copper, which precipitates part of the impurities, and in oxidising the solution, now neutral and saturated with copper, by introducing jets of air. The oxidation is said to cause the partial precipitation of the iron in the solution. However, a perfect precipitation, or anything approaching it, will take place only in a solution that has been made alkaline. The recovery of copper from the discarded electrolyte is generally accomplished as follows:—

The solution is first boiled in lead-lined tanks with granulated or scrap copper, steam and air being introduced by means of a Korting injector, so as to neutralise the free acid and to increase the copper contents of the solution to the degree desired. It is then pumped up to the crystallising tanks, in which bluestone is secured by allowing the copper sulphate to slowly crystallise out on bands of lead suspended in the saturated solution. The mother liquor siphoned off contains most of the arsenic and antimony originally present in the electrolyte, together with some remaining copper.

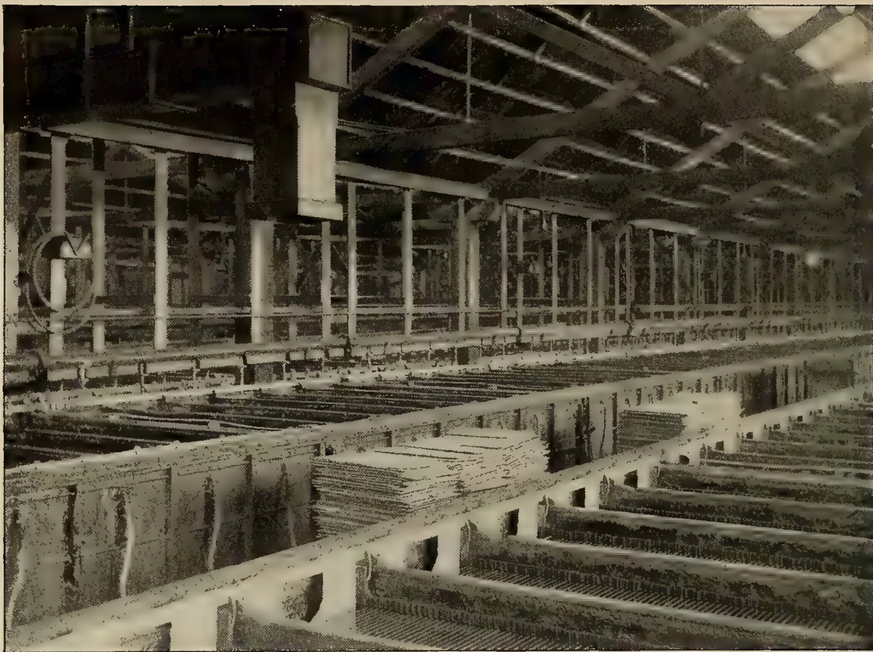
To recover the latter, the mother liquor is treated in special tanks with sheets of scrap iron. This metal first precipitates out the copper and then the arsenic, so that a black precipitate is finally secured, containing as much as 60 per cent. of metallic arsenic. The dirty precipitate is melted and reduced down into arsenical copper bars, although it might be better utilised in the manufacture of compounds of arsenic, such as Paris green.

An important improvement in the mode of circulating the solution was introduced into the above refinery. This is based upon the well-known action of Pohle's air-lift. It consists in blowing air under three or four pounds pressure into the electrolyte by means of lead pipes in such a way that solution is drawn from the tank by a lower pipe and delivered into an upper pipe, to be discharged back into the tank through a large number of perforations in the upper pipe. The electrolyte is thereby subjected to the oxidising influence of air jets, whereby the solution of some of the impurities suspended in the electrolyte is facilitated and the latter is clarified.

Many refiners believe that a large portion of the arsenic, antimony, silver, etc., found in poor cathode copper is not deposited from the bath electrolytically, but mechanically, by suspended impurities settling on the rough surface of the cathode. This is especially the case when high densities or cloudy solutions containing floating impurities are employed. The advantage of a rapid clarification of the electrolyte is therefore evident.

At first the importance of the new system was much exaggerated, especiallly as regards the removal of the arsenic and a claim was made that it would altogether obviate the necessity of the usual system of circulation. Although such statements were not justified, the fact remains that the air circulation, if assisted during two or three hours in every twelve by the general circulation of the solution from tank to tank, gives better results than the old system.

In building a refinery, the ground must first be thoroughly drained, and then the walls of the building, iron columns, trusses and the brick piers for the tanks are erected. Openings are left in the piers for the passage of the drainage launders, water and steam pipes. After roofing the building, the engines, dy-



THE TANK ROOM OF THE BALTIMORE ELECTRIC REFINING CO. AT BALTIMORE MD.

namos and compressors are placed on their foundations and the tanks on their piers. One must not omit to insert glass under each tank to electrically insulate it.

The tanks are then lined with 6-pound lead, and the conductors and pipe connections are placed in position. After the machinery has been tested and found to work satisfactorily, the cathode tanks are filled with the electrolyte prepared in large supply tanks, and loaded up with anodes and copper sheets. Electrolysis is now begun, so as to secure a supply of cathodes for the commercial tanks. Finally when a sufficient number of the commercial tanks have been filled with solution and electrodes, refining proper can commence.

The cost of the above 30-ton refinery was approximately as follows:

Building (walls, roof and trusses)	$50,000	£10,000
Dynamos and fixtures	16,000	3,200
2 Porter-Allen engines, and 1 small Westinghouse engine	11,000	2,200
Air compressor and pumps	2 000	400
Lead for lining tanks	12,000	2,400
Copper conductors	11,000	2,200
Lead burning	2,500	500
Tanks (wood work)	10,000	2,000
Lumber for floors, etc	2,500	500
Brick piers for tanks	3,500	700
Brick paving	$1,000	£200
Trolleys	2,000	400
Boiler plant (500 H. P.)	15,000	3,000
	$138,500	£27,700

The above estimate does not include cost of pipes for steam heating, nor of the tracks for transportation of material.

The reverberatory plant for casting anodes and wire bars should contain two reverberatory furnaces (10 feet by 16 feet hearth), the first with anode moulds, costing $4000 (£800), and the second, with water bosh and ingot and wire bar moulds, costing about $4500 (£900).

It would also be advisable to have a 36-inch water jacket blast furnace for reducing slag, costing complete, with electric motor, fan blower and 12 slag pots, in the neighborhood of $1200 (£240).

The remodelled Anaconda refinery, near Butte, Mont., contains an ingenious automatic register for controlling the refining operation, which the large number of tanks (1200) and the high cost of labour necessitated. Every series of five tanks in the refinery are connected

to this automatic device, which looks very much like a double dynamo commutator. A yoke carrying two brushes slides over the different sections of this double commutator, making one complete turn in an hour, and these brushes bring into contact the terminals of each series of five tanks to indicate the volts on a registering volt meter. In this way all the tanks are controlled once an hour, and the readings registered on paper automatically. This enables the man in charge to see at a glance the condition of all the tanks in the refinery. He can see at once when any trouble occurs in a tank and its nature; when it started and how it developed. He is able to point out to the foreman the tank in question, and this instrument continues to record when the man started to correct the trouble, how much time it took him to do it, and also how completely the work was done. The register costs $500 (£100) and the wiring about $1000 (£200).

The series system of refining as developed in the United States, differs from the previously described multiple system in the following respects:—

1. Special cathodes, as in the multiple system, are not necessary, one side of the anode plate serving as cathode.

2. The anodes, excepting the first and last, are not connected to copper conductors, the solution alone serving to conduct the current, and the plates are placed in series.

3. Much larger tanks than those used in the multiple system are employed, the usual size being 16 feet long, 5 feet deep and 5½ feet wide.

4. The anodes used are from ¼ to ⅜ inch thick and at Laurel Hill are 4½ feet long and 10 inches wide—*i.e.*, longer, thinner and narrower than multiple anodes. They are straightened by rolling at the Baltimore Hayden plant, and hammered straight by hand at the works of the Nichols Company at Laurel Hill, near Brooklyn, N. Y. At the latter works six anodes, weighing 65 pounds each and cast in moulds washed with bone ash, are suspended abreast in a tank and form a row. The

ANOTHER VIEW OF THE REFINERY OF THE BALTIMORE ELECTRIC REFINING CO.

rows of anodes are placed ⅞ inch apart, and the drop in potential between any two rows is therefore as low as one-ninth of a volt.

The series system is used now only by the Baltimore Electric Refining Company and the Nichols Chemical Company, a serious drawback being found in the large quantity of scrap copper produced with this process, which averages about twice as much as in the multiple process.

With the same solution, it is obvious that the voltage required per tank will depend upon the area of the plates, the distance of the plates apart and the number of plates in series. In a series tank, therefore, the electromotive force must be many times greater than the electromotive force required in the multiple tank; and where many plates are arranged in series, the voltage required to maintain a given density of current is very great, and leads to short-circuiting and other evil consequences, unless great care is constantly exercised.

One must also take into account that the slimes, as they collect on the bottom of the tank, form a large conducting plate. If the electromotive force is sufficient to overcome the resistance between the bottom of the electrodes and the layer of slimes, the current will flow partly through the electrodes and partly through the slimes, in amount inversely as the resistance of the two routes. Owing to the lessened density of current at the electrodes this will be manifest in a diminished output per tank. That such short-circuiting occurs, is proved by the fact that more copper is deposited on the end electrodes in the series than on the intermediate plates, for there the currents will recombine to a greater density per square foot of depositing surface than elsewhere in the tank. Likewise, the observed concentration of copper in the electrolyte of series processes is probably due to the combined chemical and electrolytic solution of the anode scrap in the slimes.

Series tanks are constructed of slate, or of wood, lined with some acid proof non-conductor, as a lead lining manifestly could not be employed in the series system. Slate tanks, although durable, are very expensive, as the average cost of slate for electrolytic vats is 40 cents per square foot of 1¼-inch thickness, in lengths not over 5 feet; but the cost advances at the rate of 5 cents per square foot for every additional foot in length.

Wooden tanks, although cheap (they cost about $30, or £6, each), soon become efficient conductors and lose considerable current by short circuits around the sides of the tanks, and leakage to the ground. This is because the penetration of the acid sulphate of copper cannot be prevented in tanks constructed of wood, even if lined with tarred felt and asphalted. The older the tanks, the more subject are they to these disorders. That is one of the reasons why, in the series system, only about 90 per cent. of the theoretical deposit is obtained from a given current, even with new tanks, and that the average efficiency falls far below this figure.

In two given plants, having the same cathode surface and using the same current density, the multiple system requires only one-half the anode copper used in the series system. As refineries tie up between several hundred and several thousand tons of copper each, the factor of interest on one-half of this is not to be disregarded. In series processes, therefore, the anodes are made thin, so as to obtain the maximum depositing surface with minimum weight of anodes. But the greater care which must be exercised in preparing thinner anodes, and the need of more frequently renewing such anodes than the thicker anodes used in the multiple system, entail fixed charges which about balance the saving in interest effected by using the thinner electrodes.

Maurice Barnett ably reviews the question of the relative expense of operating the two systems of refining in Peter's "Modern Copper Smelting," and reaches the following conclusion: —

In order to compensate for the extra copper used in the series system, it is the rule to economise in tanks and solution by arranging the electrodes closer together than is done in the multiple

system. With electrodes close together there is the possibility of sprouting and short-circuiting, unless the current is maintained of uniform density over the entire surface of the electrodes. Hence arises the necessity, in series processes, of working the anode copper up to a point where it is uniform, and following this by poling.

In the multiple system, the copper does not necessarily have to be improved and poled, although this procedure is not uncommon. At the Boston and Montana Company's works at Great Falls, Mont., the anodes are cast direct from the converters, thus saving the entire cost of remelting and refining the anode copper inherent in the series system. To neutralise the inevitable consequence of unequal corrosion following from such procedure, it is customary to place the electrodes from two to two and one-half inches apart. There is not then the necessity for maintaining uniform density of current over the entire surface, this inequality of density in the rougher plates being overcome by changing the cathodes rather more frequently than the anodes. Short circuiting from spouting is thus prevented, and the inequality of density of current neutralised. In the series system, "stripping" the deposit cannot be economically practiced until the tank, as a whole, is ready to be emptied.

Of course, the use of less pure copper in the anodes in the multiple system tends to make the electrolyte impure and increase the cost of refining by necessitating renewals of the electrolyte. This is true however, only, where no effort is made to keep the electrolyte free from the impurities that enter it from the anodes. At first sight, it would appear as if the extra expense in preparing the anodes would be justified, because smoother and thinner electrodes can be brought closer together, --say, to one-half the usual distance allowed in the multiple system, resulting in a reduction of the resistance between electrodes and a doubling of the output per horse-power of mechanical energy expended.

While the output is undoubtedly increased in this way, it cannot, at best, be more than double the output under the multiple system save where the anodes are rolled plates. Here the resistance between electrodes is as low as one-third that between electrodes in a multiple tank. The expense, however, of rolling the plates, and the greater cost of stripping, indicate that economy cannot be effected along these lines.

In a general way, it may be stated that the cost of improving and poling anode material exceeds the saving resulting from increased output per horse-power of mechanical energy expended. The multiple system, moreover, is free from the costly process of stripping the deposited copper from the anode scrap. This separation is frequently so difficult a matter that the deposited plate is often thrown back into the blister furnace along with the rest of the scrap.

Furthermore, the cost of maintenance of plant is greater in the series process, owing to the fact that the life of the tanks, when made of wood, is limited to about four years. Series arrangements gain slightly from the circumstance that there is less loss of energy in the conductors than in the multiple system, where there is always a consumption of about 5 per cent. to 8 per cent. of the mechanical energy of the circuit. Where coal is cheap, this is not important. The interest charges on the plant are also slightly in favour of the series system. This favourable factor of the latter is offset by heavier cost of renewals and larger interest on stock. The series system is free from the expense of making cathodes, inherent in the multiple system, but is still subject to heavy charges for stripping, amounting to four times that of making cathodes.

Balancing these various factors, as well as is possible in two works operating under the same conditions of cost of labour and fuel, there is a saving in operating expenses, in using the multiple system, of nearly $2 per ton of refined copper. This difference is susceptible of greater increase, if the refinery is run as part of a converting establishment; for, since anodes may be made

direct from the converters, the expense of making them in the reverberatory, amounting to $3.40 per ton, is altogether avoided.

In general, the greater first cost of works using the multiple system lies in the extra expense of the tank conductors and plates for making cathodes, plus about one-half of the value of the lead lining of multiple tanks, plus one-third the value of the steam and power plants. However, in spite of its larger first cost, the multiple system is, undoubtedly, susceptible of greater economy than is possible under series arrangements, as is shown by its adoption, after costly and exhaustive experiments, in works where the series system was formerly used.

To sum up the preceding points, the current efficiency of the multiple process averages 95 per cent. as against 90 per cent. for the series process under similar conditions; much less copper is held back in the multiple than in the series system, and the relative cost of operating it is less by nearly $2 per ton.

In closing, attention should be called to an important point sometimes overlooked by refiners, namely, their frequent waste of power, or the low energy efficiency of certain copper works. In some refineries this energy efficiency, or quotient obtained by dividing the energy, or current consumed in doing useful work, by the total energy furnished by the dynamo, is only 30 per cent., and in the average refinery it does not exceed 65 per cent.

The loss of energy is due partly to bad metal contacts and short-circuiting, and partly to the use of voltages much in excess of those actually required to overcome the resistance of the solution and of the metal conductors. These facts show how important it is in electrolytic refining to exercise close supervision, and how its absence is often paid for in heavy waste of energy or by its equivalent value in coal or money.

AN OCEAN DANGER AND ITS REMEDY.

By Lieut. James H. Scott, U. S. Revenue Cutter Service.

IN the days when vessels were propelled by oars, assisted, perhaps, by a sail, it was found necessary to adopt certain rules governing the passing of vessels, and the largest vessel was given the right of way. The Venetians were the first to recognise the danger of vessels meeting at night, and to counteract this they fixed to the prows of their vessels open-work, iron baskets which were filled with tow and other inflammable material. This was ignited on the approach of, or to, another vessel, and they then governed themselves as in daylight. These torches were in later years replaced by lanterns containing white lights, and many years elapsed before the use of coloured lights were adopted. Coloured lights are the foundations of the present signalling system, and are used to denote the direction taken by the vessel which carries them.

The dangers of collision prompted, some years ago, the calling of an international conference by the principal seafaring nations, and the outcome of this was a set of rules which was supposed to adequately meet the requirements. A later conference, however, became necessary, owing to changed conditions, and at this the rules were modified and the present system was adopted. A short while ago it became necessary to call still another conference, but at this little was accomplished beyond, perhaps, changing the phraseology of the existing regulations, which, in their latest shape, went into effect on July 1, 1897.

These rules were adopted at a time when a speed of ten knots was a fair average, and when only one-half of the tonnage of to-day was on the oceans; and while they may have fulfilled all reasonable requirements during that earlier period, it is not fair to assume that they can successfully cope with present conditions, with steamship speeds of 20 knots and more and a vastly increased number of vessels everywhere.

Every one has heard of two vessels colliding in daylight, and therefore can easily understand how much greater the danger becomes at night. Every seafaring man is familiar with the danger, and is looking for a system that will meet not only the existing conditions, but will satisfy also the conditions of the future, as nearly as they can be foreseen.

Let us examine the present "Rules of the Road" in the United States and see where the danger exists! It will suffice to take Articles 1, 2 and 5, which are given below.

Act of August 19, 1890, to adopt regulations for preventing collisions at sea, as amended by the acts of May 28, 1894, August 13, 1894, and June 10, 1896, and proclaimed by the President of the United States to take effect July 1, 1897.

RULES CONCERNING LIGHTS, AND SO FORTH.

The word "visible" in these rules when applied to lights shall mean visible on a dark night with a clear atmosphere.

Article 1. The rules concerning lights shall be complied with in all weathers from sunset to sunrise, and during such time no other lights which may be mistaken for the prescribed lights shall be exhibited.

Art. 2. A steam vessel when under way shall carry—

(a) On or in front of the foremast, or if a vessel without a foremast, then in the fore part of the vessel, at a height above the hull of not less than twenty feet, and if the breadth of the vessel exceeds twenty feet, then at a height above the hull not less than such breadth, so, however, that the light need not be carried at a greater height above the hull than forty feet, a bright white light, so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side, and of such a character as to be visible at a distance of at least five miles.

(b) On the starboard side a green light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two

points abaft the beam on the starboard side, and of such a character as to be visible at a distance of at least two miles.

(c) On the port side a red light so constructed as to show an unbroken light over an arc of the horizon of ten points of the compass, so fixed as to throw the light from right ahead to two points abaft the beam on the port side, and of such a character as to be visible at a distance of at least wo miles.

(d) The said green and red side lights shall be fitted with inboard screens projecting at least three feet forward from the light, so as to prevent these lights from being seen across the bow.

(e) A steam vessel when under way may carry an additional white light similar in construction to the light mentioned in sub-division (a). These two lights shall be so placed in line with the keel that one shall be at least fifteen feet higher than the other, and in such a position with reference to each other that the lower light shall be forward of the upper one. The vertical distance between these lights shall be less than the horizontal distance.

Art. 5. A sailing vessel under way and any vessel being towed shall carry the same lights as are prescribed by article two for a steam vessel under way, with the exception of the white lights mentioned therein, which they shall never carry.

To show how insufficient these rules are to cope with the existing conditions, not to speak of the increase of danger which will come with every new year, let us suppose a case that may not only happen any day, but one that has happened a score of times!

Two steam vessels, each having a speed of twenty-one knots an hour, approach each other, at night, end on, proceeding in opposite directions. These vessels, complying fully with the law, have the masthead lights visible at a distance of five miles and the side lights visible at a distance of two miles. The night is dark, the atmosphere clear, and the men on lookout pick up the lights the instant they become visible.

When the vessels are, say, five miles apart, the lookouts will report the masthead light of the approaching vessel to the officer on the bridge, who is able to see it immediately. He will, however, be unable to tell the other vessel's direction until her side lights are visible. These he will see when the vessels are about two miles apart, and are approaching the point of collision at the rate of forty-two miles an hour.

There are available two minutes and twenty-eight seconds for the ships' officers to see the lights, to make up their minds how they can best avert a collision, to give the order to port the helm, for the man at the wheel to obey the order, for the vessel to obey her helm, and for the ships to go clear. Does any one say that the time is sufficient for all these agents to perform their several functions in ample time to avert a collision?

The American line steamer *New York* several years ago collided with the British steamer *Delano* under circumstances similar to the above; yet neither of these vessels was going at such a high rate of speed. The *Delano* is only a thirteen-knot vessel, and, further, both of these vessels did not only comply with the exact letter of the law in regard to their lights, but these were visible at double the distance legally specified.

In the case above the night was supposed to be dark, with a clear atmosphere. With mist, a slight fog, or any other circumstance which would tend to obscure the atmosphere and reduce the visibility, it would, in all likelihood, be impossible to avoid an accident.

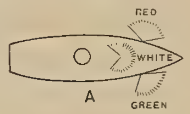
Many other matters enter into the problem and demand careful consideration. For instance, the lookout may be tired and sleepy, or may not give the concentrated attention that the nature of his duty demands. We must also recollect that the human element enters into the problem and the human element cannot be depended upon at all times.

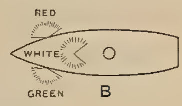
Let us suppose a case of a steam vessel, traveling at the rate of twenty knots, and a sailing vessel, at the rate of ten knots, the lights of both vessels fully complying with the requirements of the law. The sailing vessel will see the lights of the steamer in sufficient time to avoid a collision, but the rules require that a sailing vessel, when meeting a steam vessel, should hold her course; therefore, all action to avoid a collision must be taken by the steamer, and we will view the operation from the deck of the latter.

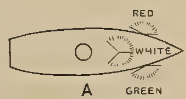
When the vessels are two miles apart, the lookout sees the side lights of the sailing vessel, and reports them to the officer on the bridge of the steamer. The vessels are approaching the point of collision at the rate of thirty knots an hour. The officer of the steamer sees the lights as soon as they are reported, makes up his mind which course will take him clear, and gives the order to

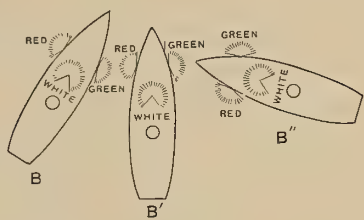
the man at the wheel to alter his course. All these various duties must be performed in less than 3½ minutes, for at the expiration of that time the vessels would be in collision. Is the time allowance sufficient for that purpose? In making the calculations for these examples, it should be remembered that a land mile contains 5280 feet, while a knot, or nautical mile, contains 6080 feet.

Anything which tends to obscure the atmosphere reduces the time limit of safety and adds to the probability of collision. It must also be understood that sailing vessels do not all carry their lights in the same position. Some vessels carry their side lights on the quarter while others carry them on the forecastle deck. This, in itself, is a source of confusion and has led to many collisions.





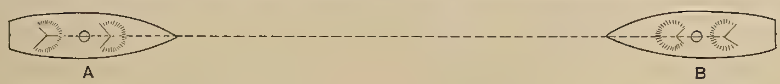


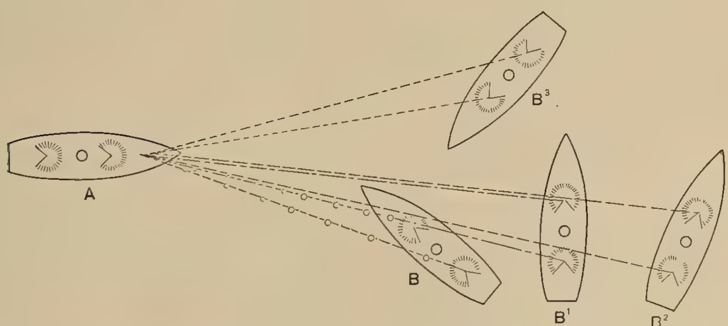


FIGS. 1 AND 2.

The first question that naturally arises is, what is the remedy, and how can it be applied? Any new system must not be such that it cannot be used in conjunction with the present one, for any radical change would be worse than the present one, by reason of the confusion that it would create.

Any system which includes the use of coloured lights should be rejected on account of the lack of sufficient visibility of such lights, and we are thus reduced to a system using only white lights. Such a system should be of the utmost simplicity, so that the instant the lights are seen they will indicate the exact course pursued by the vessel carrying them. The system should also be capable of being used in conjunction with the present lights without causing any confusion, or chance of confusion. One of the greatest faults of the present system of lights is their inability to tell the exact direction of the vessel to an observer. This fault is best explained by means of the diagrams on





FIGS 3 AND 4.

the preceding page. Using the present system it is easily seen that an observer on vessel *A* (Fig. 1) will instantly know on seeing the three lights of *B* that the latter can be heading in only one direction, and that directly for *A*, and a collision is easily avoided.

In Fig. 2, however, an observer on *A* cannot know whether *B* is going in any of the three directions or in any intermediate direction, for in each of these positions the observer on *A* will see the white masthead light and the red light of *B*, and no other. Therefore, another point to be desired in a new system is that it must show the exact direction of the vessel carrying the lights.

Long ago, realising the necessity for a change, the following system was evolved by the writer. It is believed to satisfactorily overcome many of the present difficulties. In place of Article 2 of the previously quoted act it pro vides that,—

A steam vessel when under way shall carry (a) on, or in front of, the foremast, at a height above the hull of not less than forty feet, nor higher than a distance of twenty feet below the mainmast-head, a bright white light, so constructed as to show an unbroken light over an arc of the horizon of twenty points of the compass, so fixed as to throw the light ten points on each side of the vessel, namely, from right ahead to two points abaft the beam on either side, and of such a character as to be visible at a distance of at least ten miles.

(b) On the mainmast, at a height of not less than twenty feet higher than the light on the foremast, a bright white light, similar in character and construction to the light carried on the foremast.

In addition to Article 5,—

Every sailing vessel shall carry, where most convenient, a torch or flare-up light, which shall be exhibited on sighting the lights of another vessel, from the quarter and from that side on which the other vessel is approaching. Such light shall be continued until all danger of collision is past. If the other vessel is approaching from ahead, then such flare-up light or torch shall be exhibited from the forecastle deck, from the point where it can best be seen, and shall be continued to be so shown until all danger of collision is past.

This system offers great simplicity, as only two lights are used, and they show the exact course which the vessel carrying them is pursuing. This is better shown by Figs. 3 and 4. In Fig. 3 an observer on steamer *A* cannot mistake the direction of vessel *B*, for the lights of *B* are in range; that is, one light is directly over the other, and *B* could not possibly be going in any other direction. Further, an observer on *A* will instantly know when *B* changes his course to avoid collision and how great a change is made, for the instant that *B* makes the slightest alteration in his course the lights will move apart. The greater the change in the course, the greater will be the change in the position of the lights.

In Fig. 4 an observer on *A* will know the exact course pursued by *B*, and cannot mistake it for the course pursued by *B1*, *B2*, or even *B3*, for in *B3* the after light shows the true direction.

The system here proposed would not only not interfere with, but would assist, the present one. In foggy weather, with the fog lying low, a lookout, placed at the masthead, would not only be able to see the lights of the other, but would be able to define her course with as much certainty as if the weather were clear.

POWER STATION LOAD LINES.

By Arthur Vaughan Abbott, C. E.

ALL manufacturing processes involve two factors, raw material and energy, the combination of which effects a finished product of more value than the sum of the factors, and it is the province of engineering to so adjust the relative amounts of raw material and energy as to produce the desired output with the least expenditure. Economy in material has received the closest attention, for, owing to its tangible character, it is easy to measure. Not so with energy. Utterly illusive, and derived from a waterfall or coal pile, by the intervention of complicated machinery, and dissipating itself most subtly in a thousand unexpected channels, it has long successfully resisted analysis.

The consideration of the energy factor may profitably be resolved into two parts:—

First. An estimate of the energy required.

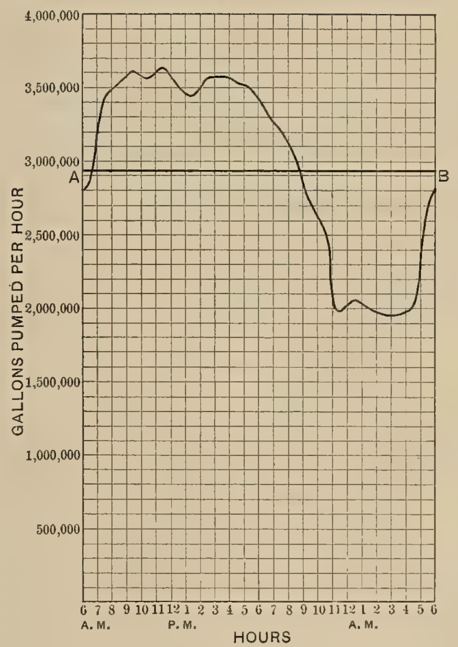
In projected enterprises, such study leads to a statement of the power required, and a calculation of cost as a basis of the proper idea of the expense of this part of the process.

In processes in operation such an analysis determines the total amount of energy supplied, and traces its expenditure through all the various ramifications of the art, enabling a balance sheet to be prepared.

Second. An examination of efficiency.

From the balance sheet it is possible to analyse in detail the energy expenditure, determining what relation each item bears to the total amount, and to ascertain whether any part of the process can be improved.

To perspicuously present such an analysis for consideration and record, it is customary to make use of diagrams, in which the abscissæ are allotted to time intervals, and the ordinates to power consumed. The resulting curve is a line indicating the time-power relation, and is termed a "load line." Fig. 1 gives a daily load diagram of the Chicago City Water-Works. The ordinates denote the gallons pumped per



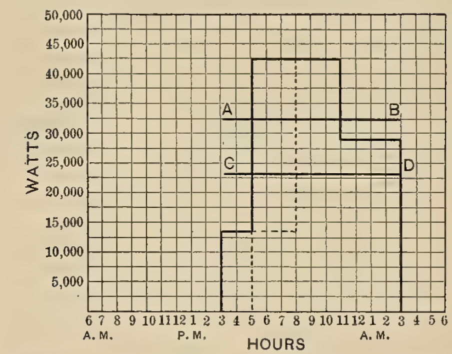
Max. H. P. 1576
Mean H. P. 1272
Min. H. P. 845
Load Factor .... 80.81 Per Cent.

FIG. I. DAILY LOAD DIAGRAM OF THE CHICAGO WATER-WORKS.

hour, while the abscissæ record the hours of the day. At 6 A. M. the output is 2,800,000 gallons per hour, the consumption raising rapidly to a maximum at 9.30 and again at 11 A. M., reaching 3,640,000 gallons.

The curve then falls until 1.30 P. M., while in the afternoon a second maximum at 3 P. M. reaches 3,580,000 gallons; but it is notable that the afternoon demand does not reach that of the forenoon. From 3.30 P. M. the output rapidly declines, reaching a minimum at 11.30 P. M., while between 1 and 2 A. M. an increase may be noted, due to the demands of street cleaning. A second minimum occurs at 3 A. M., from which time the consumption again increases.

A peculiar feature of all diagrams connected with municipal supply is the correspondence exhibited to daily avocations. The greatest diurnal output is seen to be in the forenoon, while between 12 and 2 P. M. the effect of the universal lunch hour is marked, though it is curious to note the retardation of the standpipe as affecting the minimum of the curve of water consumption. The resumption of daily avocations in the afternoon is the origin of the second maximum, but failure to reach the morning rate denotes that the greatest volume of work is performed before noon.



Maximum H. P. 60
Summer Load Factor .... 22.2 Per Cent.
Winter " " .... 37.7 " "

FIG. 2. LOAD DIAGRAM OF AN ARC LIGHT PLANT.

A simple load line is that obtained from an arc light station, as indicated in Fig. 2. The plant is provided with a capacity of about 100 arcs. The output in watts is indicated by the ordinates, while the corresponding times are given by the abscissæ. The winter load is shown by a full line, and the summer one by a dotted line, from which it appears that at 3 P. M. in winter the commercial arcs are started, requiring an output of 13,750 watts. A 5 P. M. the municipal lighting is required, increasing the demand to 42,500 watts.

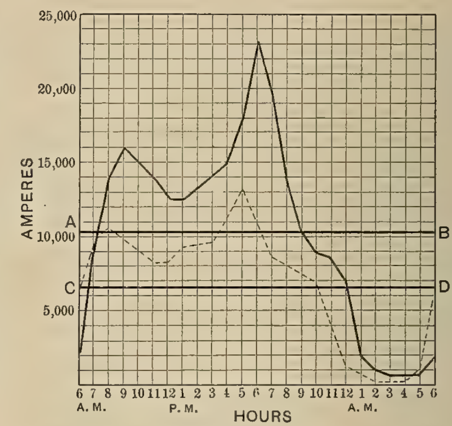


FIG. 3. LOAD DIAGRAM FOR THE WEST END STREET RAILWAY CO., BOSTON.

The line then runs horizontally to 11 P. M. and then decreases to 35,000 watts, by the removal of the commercial lamps, while the municipal load remains until 3 A. M. The summer diagram is similar, excepting that the commercial lamps are not lighted until 5 P. M. and the municipal lamps at 8 P. M.

A load line from the West End Street Railway Company at Boston is exhibited in Fig. 3. Both summer and winter lines are shown, indicated by the dotted and full lines, respectively. It is interesting to note that in summer the maxima occur an hour earlier than in winter, and the winter load rises to 23,400 ampères, while in summer it is only 13,400 ampères.

Figs. 4 and 5 are the lines derived from the St. James Power Station in London, supplying incandescent lights upon the Edison three-wire system. The full line in Fig. 4 is the winter load, while the dotted line is that for summer, and forcibly portrays the variation to which such a station is subjected. The winter load shows a maximum of 3200 ampères, with an output of 7242 K. W. hours, while in summer the load barely

reaches 1190 ampères, developing 1973 K. W. hours.

Fig. 5 is the annual load curve of the same station. From January 1 the load steadily decreases to August 1, though it would naturally seem that the lowest point would coincide with the summer solstice. This retardation of the minimum point is due to summer vacations which take place to a great extent in August, and, though the days are somewhat shorter, a less amount of current is demanded. Similarly, the maximum point of the curve occurs on November 1 instead of on December 21. This is owing to the competition of fall trade, causing an increased amount of business to demand a greater supply of current than would be called for by the actual number of lighting hours. A greater proportion of cloudy days also occurs in November and in the early part of December than in succeeding months.

An interesting municipal diagram is that afforded by a gas works, as indicated in Fig. 6, showing the output of the London Gas Light and Coke Company for typical days in June, December and January. The curves are respectively designated as Nos. 1, 2 and 3. From No. 1, it will be seen that from 8 A. M. to 8 P. M. the load is about constant and about 1 million feet. From 8 P. M. it rises to a maximum of 4.6 million cubic feet at 10 P. M., and then declines to a minimum at 6 A. M.

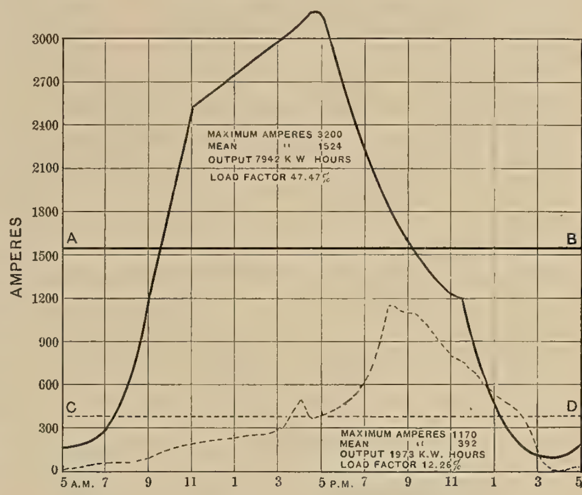


FIG 4. LOAD LINES OF ST. JAMES STATION, LONDON.

The average winter curve is that given in No. 3. There the day demand is $3\frac{1}{2}$ million cubic feet, and at 2 P. M. the load rises, reaching 9.6 million cubic feet at 6 P. M. For a foggy day, curve No. 2 shows a morning maximum at 11 A. M. of $6\frac{1}{2}$ million cubic feet, and an afternoon peak of 10 million cubic feet.

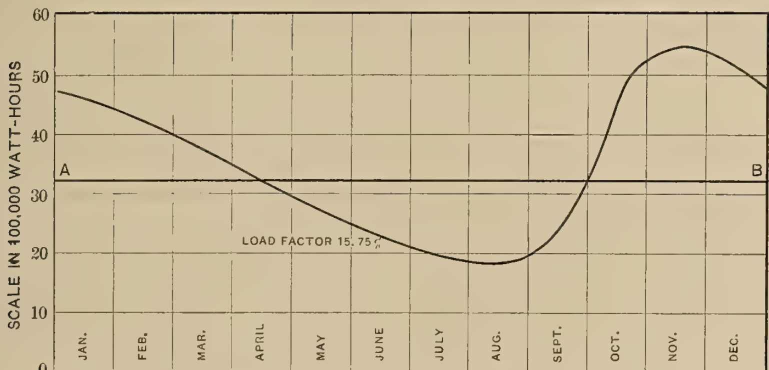
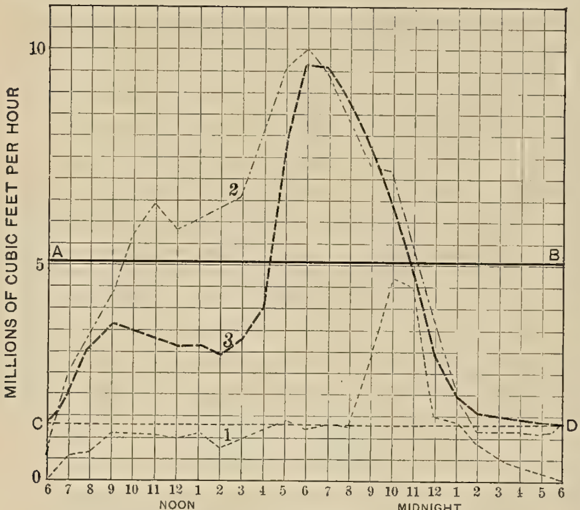


FIG. 5. ANNUAL LOAD CURVE OF ST. JAMES STATION.

These load diagrams, cited from a large collection, are indicative of average manufacturing operations; they exemplify the method of construction and their

value. In all of the lines, the salient peculiarity is the unsteadiness of the demand, and the design of every power plant must recognise maximum requirements, and provide sufficient machinery to meet the heaviest loads. In addition, a sufficient surplus must always be allowed as a reserve against accident. This is particularly important in municipal installations, as the public is a most capricious customer, and ill brooks the slightest interference with its comfort.



Maximum Output.................................. 10,000,000 feet.
Load Factor, Winter.............................. 52 Per Cent.
" " Summer .... 16 " "

FIG. 6. LOAD DIAGRAM OF THE LONDON GAS LIGHT AND COKE CO.

In the design of a power installation it is first necessary to determine the maximum of the probable load diagram, as an index of the necessary capacity. Machinery called upon to meet sudden variations will work more uneconomically than that upon which the load is sensibly steady, and it is apparent that the nearer a plant can evenly operate at its maximum capacity, the more economical will it be. Therefore, the primary value of the load diagram leads to such an adjustment of the capacity to demand as will be conducive to maximum economy.

In gas manufacturing it is possible to arrange the holders so that the process of distillation may be uninterruptedly carried on at such a rate that the aggregate in each twenty-four hours shall be equivalent to the daily demand, 90 per cent. of which occurs between 4 and 11 P. M.; so this part of the plant may be designed to meet the average load. The distributing system, however, is subjected to fluctuations, caused by varying hourly demand, and must have sufficient capacity to carry the maximum volume of gas; consequently, the pipe lines cannot be as economically worked.

From Fig. 1 the diurnal demand upon the water-works requires a variation in power expenditure of 731 horse-power. An examination of the other diagrams indicates that, in each instance, the plant is periodically subjected to severe loading, to which its machinery must unfailingly respond. The time element must be examined in a similar manner. While for water-works, gas works and incandescent lighting stations a 24-hour run for each day in the year is universally maintained, arc lighting plants, railway installations and a multitude of ordinary manufacturing enterprises often operate for only a fraction of each 24 hours, and sometimes entirely suspend on holidays, so that efficiency is proportionately decreased.

In discussing efficiency, the term "load factor," as indicating the relation between the actual energy output of any plant, as compared with its possible maximum capacity, has been accepted. The maximum output of the Chicago Water-Works (see Fig. 1) is 1576 horse-power, while the average load, as indicated by the line *A B*, is 1272 horse-power, giving 80.81 per cent. as the daily load factor. The West End Railway (Fig. 3) shows a factor of 44.5 per cent. for winter, and 29.1 per cent. for summer. St. James Station indicates a daily load factor in summer of 12¼ per cent., and in winter of 47.47 per cent.; while the annual factor is

15.75 per cent. The London Gas Light and Coke Company realise a summer factor of 16 per cent. and a winter factor of 52 per cent.

If the load factor could be made 100 per cent., the plant would operate uniformly, both as to output and time, so that, evidently, the higher the load factor, the greater the economy.

The expense of any energy factory may be separated into two parts, one of which depends entirely upon the capacity, while the other is a function of the output. The size of the machinery; the amount of real estate and buildings; the interest and depreciation upon the entire investment; taxes; a portion of the fuel; and a small fraction of the labour, are dependent only upon the size of the plant, while other items, such as the larger portion of the labour, fuel, oil, waste and other supplies are dependent upon the output. Unfortunately that fraction of the whole expense which is included in the first category is by far the greater proportion, usually aggregating one-half or three-fourths of the cost of production.

Stations having load lines showing a high maximum for a short time with a low average, are the most expensive to operate, and, therefore, study should be directed to depress and widen the peaks, and to elevate the general average. In a gas works it is possible to do this with that portion of the plant which is occupied in distillation; but the distributing system must inevitably bear fluctuations, due to variation in demand. Water-power plants may be adjusted by building reservoirs of sufficient size.

In London and Paris power supply systems are in operation, involving distribution by compressed air, and by hydraulic power. So far as the generating systems are concerned, they may be operated to give high load factors; for the air compressors and water pumps can run at an average uniform load, supplying the desired air or water to receivers which shall store a sufficient amount to meet the daily variations in demand.

With ordinary steam installations, much thought has been expended in endeavours to improve the load factors, with very partial success, as there is no known method of storing energy obtained from the steam engine. It has been proposed to improve boiler efficiency by designing boiler plants of such size as to furnish steam to carry the average demands; during the hours of low load the boilers are to be kept continuously at work, the surplus heat being stored in highly heated water, kept from evaporating by being retained under a pressure greater than the vapour tension called for by the temperature. Theoretical calculation shows that, notwithstanding the inevitable losses by radiation, such a scheme might show economy, but as the system is practically new, it would have to face the unexpected which always tends to increase expenditure.

The substitution of gas engines for steam engines presents a field which European experience indicates to be promising. By means of the gas engine that portion of the plant which is included in the boilers and coal handling machinery may, by the substitution of gas producers, operate at a uniform load. Practice has also shown that gas engines of large size show an economy equal to the very best triple expansion condensing engines; but the manufacture of such machines has been so recent as to miss the thoughtful attention that is necessary to fully perfect such apparatus.

For electrical plants the use of accumulators as a means of steadying the load diagram is a favourite method. Theoretically, the generators could be operated uniformly, provided sufficient accumulator capacity were arranged to absorb and store the surplus energy developed during hours of light load, and European experience has justified the value of this practice. In America, results have not been so favourable. This is partially attributable to the higher load factors there, the average being 35 per cent. to 40 per cent., against 15 per cent. to 20 per cent. in Europe. In America the storage battery industry has for so long been involved in legal complications that central station man-

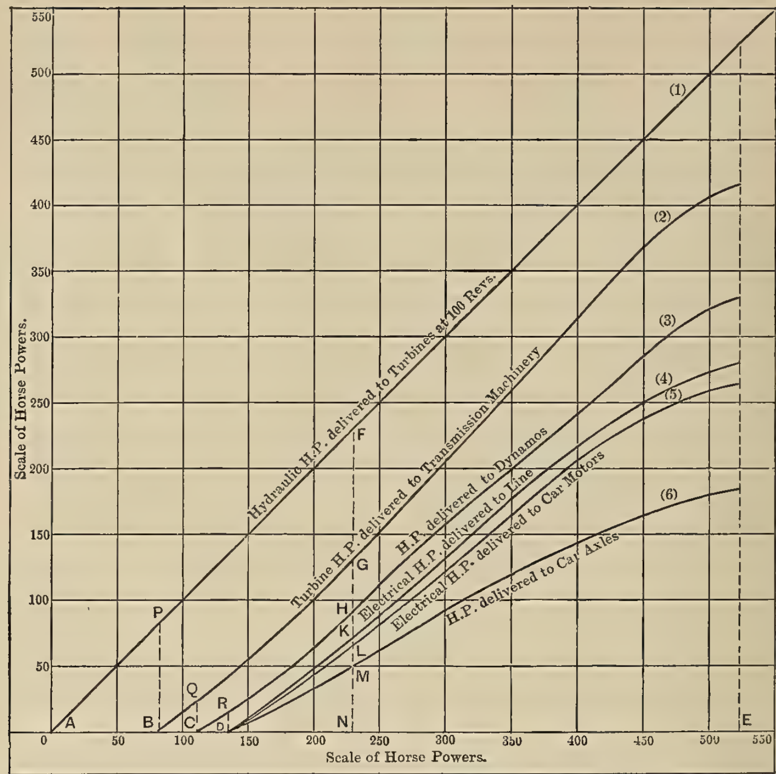


FIG. 7. CURVES OF POWER DISTRIBUTION FROM HYDRAULIC H. P. TO CAR AXLE H. P.

agers have been reluctant to invest in plants, as possible subjects of litigation.

The accumulator has been passing through a period of experimental development, involving its action in so much obscurity as to preclude reliable estimates of life, and prevent any accurate knowledge of the true rates of deterioration. Spurred by competition, manufacturers overrate their product and the resulting list of battery plants consigned to the scrap heap is disheartening. Finally, the prices charged by American makers, together with their reluctance to assume the responsibility for imperfect manufacture, has made the American storage battery installation almost an unknown type. As German prices are about 0.6 as much per unit of capacity as American, and as German manufacturers will insure perpetual maintenance at 4 per cent. on the cost of the cells, the slow progress of American accumulator plants is not difficult to understand.

The requirements of consumers may be modified to greatly improve the load diagram. For electrical plants this may be accomplished by stimulating the use of motors, and the consumption of electricity for cooking and heating, by supplying current at attractive prices during the hours of light load. It has been suggested to arrange a sliding scale and to meter the energy delivered to the consumer in such a way as to note the time at which the maximum load occurs, as well as the amount, and arrange the scale of charges in such a way as to stimulate uniform consumption.

An example indicates the expediency of such a course. Suppose there are two customers, *A* and *B*, each consuming 1000 K. W. hours per month, but that *A* takes a steady supply for 20 hours per day, while *B's* demand is

compressed into $1\frac{1}{2}$ hours per diem. Assuming an average cost of equipment of $300 (£60) per K. W. of station capacity, 16 per cent. interest and depreciation on cost of plant, 6 cents (3d.) per K. W. hour as cost of energy delivered, and 10 cents (5d.) per K. W. hour as selling price, the accounts of *A* and *B* will stand as follows:—

$\frac{1000}{30 \times 20} = 1.666$ K. W. hours per hour = *A's* demand.

$1.666 \times \$300.00 = \$499.99$ cost of station plant to supply *A* — say	$500.00	(£100)
Interest and depreciation $500.00 × 16 per cent =	$80.00	(£16)
Cost of energy 12,000 K. W. hrs. @ 6c =	720.00	(£144)
Total annual cost to supply *A*	$800.00	(£160)
Income 12,000 K. W. hrs. @ 10c	1,200.00	(£240)
Profit	$400.00	(£80)

$\frac{1000}{30 \times 1.5} = 22.222$ K. W. hours per hour *B's* demand.

$22.222 \times \$300.00 = \$6,666.66$ (about £1334) cost of station plant to supply *B*.		
Interest and depreciation $6,666.66 × 16 per cent =	$1,066.66	(£214)
Cost of energy 12,000 K.W. hrs. @ 6c	720.00	(£144)
Total annual cost to supply *B*	$1,786.66	($357)
Income 12,000 K. W. hrs. @ 10c	1,200.00	(£240)
Loss	$586.66	(£117)

In both these examples the same amount of energy is sold at the same gross income, yet in the first instance there is a profit of $400 (£80), and in the latter a loss of nearly $600 (£120). Representing by *C* the cost of installation per K.W.; *i* the rate of interest and depreciation; *c* the cost per K. W. hour for fuel, labour supplies, lost energy, etc., to deliver one K. W. hour to the consumer; *P* a fair profit per K. W. hour; *p* the percentage of total time that each customer demands supply; and *K* the number of K. W. hours consumed per annum, $K\left(c + P + \frac{Ci}{8760\,p}\right)$ will be the equitable charge to each customer. The objections to a sliding scale are the additional bookkeeping involved and the dissatisfaction likely to arise among customers who are apparently charged different amounts for the same service.

Assuming the plant to have been adjusted, internally and externally, as economically as possible, the load diagram fulfils another valuable office in indicating the disposition of energy, and becomes a balance sheet that determines upon the debtor side the total power developed, while on the creditor side the various items and methods of expenditure must account for the power output.

A load diagram in balance sheet form, worked out in an exceedingly valuable manner, is that given in Fig. 7, as the result of an examination into the performance of the Neversink Mt. Railway made by Mr. W. S. Aldrich.* Both the horizontal and vertical axes are devoted to power ordinates. The 45° line represents the hydraulic H. P. delivered to the wheels, while the successive curves, 2, 3, 4, etc., are indicative of the amount of power transmitted to the various other parts of the entire system. To determine each such relative amount, find, upon the left-hand vertical axis, the amount of power at which the plant is operating, follow a horizontal to curve 1, thence a vertical to the curve of that part of the plant of which the efficiency is desired, and from this intersection a horizontal to the left, reading upon the vertical axis the amount ot power delivered. For example, supposing the wheels are receiving 250 H. P., and the amount delivered to the car axles is desired. From 250 on the left hand axis follow a horizontal to curve 1, thence a vertical to curve 6, thence a horizontal to the left-hand axis, finding 50 as the power given to the car axles.

Examples could be multiplied without limit, but enough has been said to show that manufacturing without load lines is like banking without a bookkeeper. In each case the thoughtful engineer will derive unerring information as to economic conditions, which, if faithfully accepted and followed, will place the energy factor on a basis of maximum economy.

* Trans. Am. Soc. M. E. Vol. 15, page 705.

PRIMARY TECHNICAL EDUCATION IN INDIA.

By John Wallace, C. E., Editor of "The Indian Textile Journal."

THE commercial utilisation of raw products and the progress of industries and manufactures have of late years excited much attention in India, and have brought the subject of technical education into very prominent notice. It has, at the same time, disclosed a great diversity of opinion regarding the methods that should be employed in order to increase the industrial capacity of the artificer classes.

To avoid ambiguity I shall deal with the term "technical" in its most literal sense, as that part of knowledge which cannot be acquired by reading and writing, and which forms the art of any kind of work. The use of a hammer, a file and a chisel are arts that can be acquired only by manual training, and in this respect they form a totally distinct class of knowledge from that contained in the books of Hurst, Molesworth and Trautwine. The progress of human knowledge has been from the art to the science of work, the former leading up to the latter; but no amount of purely scientific knowledge would confer the art of handling tools, or even of wheeling a barrow.

Similarly, I would define education as a result of instruction that can be formulated only when the object of the education is clearly known. For instance, if a man lives beyond the range of books and newspapers, and has no letter-writing to do, he would find a literary education of no use; but if he has to earn his living by any kind of labour, knowledge, bearing on his work, would be of the first importance to him.

It was with this object that apprenticeships were first instituted long before scholastic education reached the working classes, and the old-fashioned apprenticeship may be regarded as an example of purely technical instruction in the arts of a trade. The apprenticeship is dying out because its methods of instruction were slow and irregular, for the art of teaching a trade does not always accompany the capacity to follow it; and we now look to technical education to supersede, by precise and well-considered methods, the uncertain and inferior effect of an apprenticeship.

The object of this paper is to show that in India among the labouring classes the instruction most needed is of a non-literary character, referring directly to the work by which the labourer lives, and improving his knowledge of it so as to increase his wage-earning capacity, and, with that, the industrial progress of the country. It is generally recognised that industrial progress is based on the skilfulness of the workman, and upon the excellence and cheapness of his methods of work, and it concerns India as much as any other country that her people should be skilful and economical of their time, labour and material.

It has been found, however, that, with few exceptions, the Indian workman, when compared with the European, is under many disadvantages through defective training and methods, and that with the same amount of physical exertion, he performs much less

work. The difference between the Indian and the European, each working in his own country, varies with different classes of labour, but in proportion as skill and method are employed, the superiority of the European is manifest, giving advantages for which no difference in wages can compensate; as, for instance, in the making of parts of textile machinery or fine instruments.

Generally speaking, the Indian artificer has a low standard of workmanship and finish, and in this respect he is far behind the Japanese, who, with a very similar kit of tools, and without the use of sandpaper, turns out the beautiful cabinet work which is now so well known.

Before dealing in detail with the defects of the Indian artificer, or with the training he requires, it will be well to consider what has been done, so far, to promote a higher standard in the country.

The system of general education in India has been hitherto almost exclusively literate, and has had no appreciable effect on the workman. The instruction in primary and secondary schools has no direct bearing on any art or handicraft, and its effect on skilled labour has not been found to be beneficial, as it tends to detach the pupil from his trade and to draw him to clerical work, which occupation, in the East, is considered more desirable and honourable than any trade. There are, it is true, drawing classes in a number of these schools; but of the students who learn drawing only a small number are, or ever will be, artisans, the majority of them being past the age at which Indian boys learn a handicraft.

In addition to these schools there are a few isolated industrial schools and classes, but these in no way meet the necessities of the country in technical instruction. There are also a few science and technical colleges, but these have had practically no effect on the workman, as their students get only a smattering of handicraft in the few hours a week allotted to the workshop, and cannot, therefore, be fit, on leaving college, to undertake the instruction of craftsmen.

PARSEE CABINET MAKERS.

MAKING CARVED AND INLAID BOXES.

The educational system in India follows too closely that of England; it has been too readily assumed that a system, based on the needs of the people in Europe, is suitable for India, and on this presumption a great deal of money has been spent, with results that have come very far short of what was expected.

In this respect we, in India, have to deal with education very much as we did in our attempt to burn the refuse of our cities with furnaces of European model, until, after several failures, it was tardily discovered that the Indian refuse was quite different from that in England, and would burn properly only in a furnace designed in India after a thorough study of the material to be destroyed.

The study of the material, from the educational point of view, has not been entirely neglected in India, for I find in the *Calcutta Review* for April and October, 1883, an excellent paper in which Mr. I. C. Nesfield, lately the Director of Public Instruction in the North West Provinces and Oude, tells some of his experiences with education in that part of the country. It can be seen, from what he says, how little bearing the present system of education has on the necessities of a large part of the community, and also how capable and skilful the entirely illiterate Indian artisan may become with the aid of proper technical training.

Speaking of the effects of primary education on the children of cultivators, Mr. Nesfield finds that it makes them less contented with their lot in life, less willing to work and more litigious. They go back to the plough with the greatest reluctance, and some positively refuse at first to work; their ambition, if they have done well at school, is to get clerical employment.

Mr. Nesfield states that out of 3024 scholars who had left school, he found 2165 with whom he could communicate, and these he invited to be examined in the subjects in which they had received instruction. Out of these, 1037 accepted his invitation, with the result that 16 per cent. passed in one or more of the simple subjects (reading, writing and arithmetic) and in one or other of the three more difficult grades, while the remaining 84 per cent. failed to pass in any one subject or in any of the three more difficult grades. It appears that

the instruction imparted to them at school was of no use to them in their daily avocations, as they had neither reading, writing nor calculating to do, and they forgot their schooling as people forget other things that they do not practice.

Education did not make better agriculturists of them because their instruction did not include anything directly bearing on agriculture. On the contrary, they seem to have been the worse rather than the better for their schooling, as the most receptive period of their lives had been occupied with almost useless studies.

In strong contrast to the above, Mr. Nesfield gives a picture of another educational establishment,—the workshops of the Oude and Rohilcund Railway at Lucknow, where the instruction is directed exclusively to the business of bread-earning by non-literary methods. Here he went around the works with one of the chief European officials of the company, and had personal conversation with the men.

Among his notes are particulars of seventeen foremen and leading hands, all picked men of superior ability, having, each, charge of from 15 to 400 workmen. These foremen, says the writer, are the most intelligent, the most skilful and the most trustworthy Indian workmen in the company's service, and only one of them had ever seen the inside of a school, and that in his early boyhood. Mr. Nesfield remarks finally that "probably if Professor Huxley were now (1883) in Lucknow, he would affirm that the railway workshops, which are employing some 2000 men and about 80 boys, are doing more to educate the masses than the principal schools; and he would be the more convinced of this if he looked to the good which these workshops are doing in teaching punctuality, application to details, thoroughness of workmanship,—in short, forming the character, which,

HINDU COPPERSMITHS SHEARING PLATES

HINDU COPPERSMITHS.

after all, is the main result that education is intended to secure."

This, from a man high in the Educational Department, must have caused considerable surprise when it appeared. To this may be added another instance of technical education on a large scale which, for more than thirty years, has been in active progress in India. I refer to the cotton mills whose operatives have nearly all been taken from the agricultural class and instructed by specialists, who, until recently, came from England.

These specialists had been trained in the mills, and, beginning at the very bottom of the factory scale, had mastered every detail of their business and had thus become competent instructors. The training they gave to new hands soon increased the wage-earning capacity of the operatives, so that it was, and still is, common to see a boy whose value before entering a mill was only R 2 per month, develop to R 6 in value within one month in the spinning room.

The railways and mills keep all their good men, but beyond training their own employees they do very little towards supplying the enormous wants of the country for better workmen. Still, they have done enough to alter, to a very important degree, the ideas that have hitherto been prevalent on the subject of technical education, for they have proved that it is far more easy to raise a man's wage-earning power by a non-literate than by a literate method of instruction. And as good workmen are a first necessity in a country that would increase and develop its industries, the most effective method of training them

should be recognised and adopted by the Educational Department in all cases where it is desired to raise the standard of workmanship in the labouring class.

It should not be forgotten that the progress of the industries in Europe has been from below upwards,—that the arts preceded the science of labour, and that the richest manufacturers as well as most of the men of scientific genius have sprung from the ranks. It is well known that poor and illiterate youths have become wealthy manufacturers, and also well-educated men in a general sense, the education being the outcome of their work; and yet, in spite of all this experience, the principal efforts of the government in India for the advancement of local industries have been directed to the education of masters.

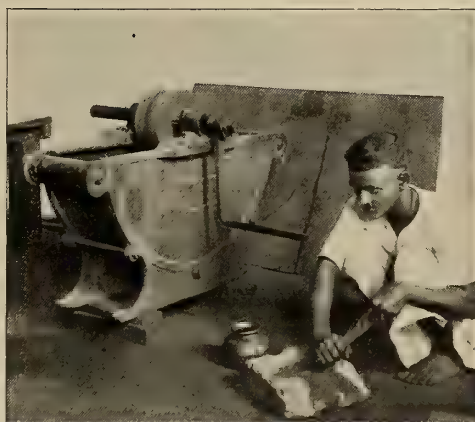
The result, so far, has not been encouraging. The educational masters have not been able to impart the requisite knowledge to their subordinates, and progress has not followed in the manner expected.

This lack of progress will continue until it is very clearly understood that the Indian youth cannot be educated in science by the methods in vogue in England. His strength of memory and his capacity to cram for examinations are, doubtless, gratifying to teachers whose success is measured in marks gained by their pupils; but they are the despair of employers who discover that the young men, instead of using their principles and formulæ as tools in a workshop, would rather handle them as charms and talismans, upon which the whole responsibility of results should be thrown. They do not learn to think in terms of material, strength, proportion, durability and cost, and many can never break the habit of seeing their whole duty through the light of a text-book. It is, therefore, no wonder that they cannot train workmen. Training on a non-literate principle may, therefore, now claim a trial.

The training of the artisan may be broadly divided into two stages. In the first he should acquire a thorough knowledge of the use of hand tools; and in the second he should learn to use and construct for himself cheap and simple labour-saving appliances. The training of the Indian workman is, at present, very defective in the first of these stages, and of the second he is practically quite ignorant.

With regard to work belonging to the first stage of training, the use of hand tools, we find that the average Indian artificer, in the building and repair of houses, is chiefly remarkable for the inaccuracy of all he does, for the blunt condition of his tools, and for his ingenuity in making excuses. Away from large towns he is usually without a foot rule, and has never seen a grindstone.

Let us take the wood-worker as a typical example, and inquire into what he most needs in the way of education! His methods are very defective. His tools are blunt as a normal condition,—so blunt as to greatly retard his speed and ease in working. This arises from his defective means of sharpening them. His whetstone is too small and is never



THE ABANDONED GRINDSTONE.

flat on the surface, so that it always produces a rounded cutting edge.

If provided with a good and smooth grindstone he straightway cuts it into grooves, and otherwise abuses it until it is unfit for use; he then returns to the original method without a thought of putting the grindstone in order. This

may be seen in Bombay at the present time. It has been urged that the grindstone is too expensive a tool for a native carpenter who has a small fixed workshop; but this is absurd, as it may be made of any sandstone and may be mounted entirely in wood, including

A HINDU WOOD-TURNER.

axle, bearings and handle. All sandstones are not equally good, but any one is better than the whetstone as at present used.

The sharpening of saws comes next in order. It involves an outlay on files which the carpenter is loath to make. I have met only one Indian workman who, without compulsion, kept his saws in good order. The general result is an enormous amount of needless labour that a sharp and well-set saw would obviate. Cutting close up to a pencil line, or cutting it out altogether,—an operation that any European apprentice can perform,—is an unknown art among most Indian workmen.

Accuracy in measurement is similarly neglected, because the Indian workman has yet to learn that it is more easy to be correct than incorrect; that is to say, the correct man loses the least amount of time and labour.

Again, in his attitudes at work the Indian is frequently wrong. He sits to certain operations, such as hand-sawing and planing, that would be done with less expenditure of muscular force when standing. To the sitting position, when it suits the work, there can be no reasonable objection.

Of drawing he knows little or nothing, but he is capable of learning to make hand sketches of details of work, and of placing dimensions on them in a very short time if the subject is properly presented to him at the right age. This ignorance of drawing renders it very difficult for him to undertake and carry out any new work from description. He requires a model from which to copy.

All the things I have mentioned may be taught and well taught without the intervention of a spelling book, and their utility is so obvious and so suggestive of good wages that the business of the school would be much more agreeable than in classes where the three R's are the staple of mental nourishment. Even the making and testing of a flat ruler or straight edge may be taught to boys who have never heard the definition of a straight line, although there are many students of advanced mechanics and mathematics who would be quite at a loss to perform this simple operation.

The matters just dealt with all come within the scope of the first stage of technical instruction; they all belong to that part of the art of labour which no literary study will impart, and which can be acquired only by practice with the hand and eye.

The second stage, which, although usually associated with literary acquirements, is really quite independent of

them, enters into the economy of labour, and deals with machines and appliances for expediting work—not the expensive machine tools that are imported from Europe, but such machines as may be made by the workman himself with the aid of the hard and durable woods so common in India.

The disregard of our local workmen results in their being unable to make anything exactly to pattern or to make any number of things alike. Each separate operation involves a separate measurement, with a strong probability of error in it. To obviate this, gauges must be used for work that has to be repeated, and when the gauge is fixed mechanically on a work table, and the cutting instrument is rigidly fixed in a certain relation to it, instead of being in the hand, we have together the elements of a machine tool that will perform the same operation any number of times in exactly the same manner.

It does not matter, mechanically, of what material the machine tool is made so long as it fulfils its purpose; but the difference in cost of a good home-made appliance and that of a machine made in Europe for the same purpose may be enormous. The latter, as an article for exhibition and sale, may be far superior to the former, and capable of doing a great variety of work, but if the variety is not needed, the advantage of it disappears.

Brass-workers in Bombay, Poona, Nassick and elsewhere are importing elaborate slide and screw-cutting lathes, entirely of steel and iron, to do work which is done to-day in Birmingham on lathes with a bed and fly wheel of wood, each turner treading his own lathe instead of employing another man, as in India, for this work. Gas fittings, garden syringes and numerous other articles are thus made in England for the Bombay bazaar at prices that the native worker cannot, at present, approach.

The principal machines that a workman may make for himself are the lathe, the circular saw, the fret saw and the drilling machine; and among the many uses to which these may be put the following may be mentioned. In the making of doors, windows and shutters, the small circular saw, with two blades, cuts and shoulders tenons with speed and accuracy, while the drill prepares the mortises by making parallel holes at each end of the recess. Louvre boards are cut to length and shouldered by the circular saw, while a tube saw, made of sheet iron or steel, and fixed in the lathe, cuts the pins at each end to cyl-

INDIAN ART POTTERS AT BOMBAY.

indrical form and of standard diameter. The drilling machine makes the holes for these pins all in the right position in the shutter frame, and parallel with one another without measurement when once adjusted.

The foot-lathe, which every pupil should learn to use, may be made largely of solid bamboo, with wooden fly wheel, axle, bed and headstocks. It is good for both wood and brass turning, and screws may be cut on it with hand tools. Small circular saws, from four to six inches in diameter, are often used in the lathe for a variety of work. The extension of the No. 1 stable of the Bombay Tramway Company was put up with the help of such appliances. The circular saws were from a worn-out cotton gin, and were mounted in a very common joiner's lathe, and the tube saw for forming pins on the hundreds of louvre boards was of common iron. No paring was necessary on the work. The device was afterwards used for making the frames of notices hung in the tramcars.

The object to be aimed at in the training of workmen is to make them self-reliant and as independent as possible of machine tools which they cannot make themselves and which are to be found only in the large towns and manufactories. Away from the large workshops the properly trained workman should be able, like the European millwright, to rely on his own ingenuity. Men so trained have no difficulty in learning the use of machine tools when necessary.

The training of blacksmiths should be such as would enable them to do their work almost exclusively on the anvil, like those smiths of the eighteenth century in Europe who were proud of only such work as showed no trace of file, chisel or rivets. A first-class smith can forge every detail of a rose-spray out of charcoal bar iron, and weld them together afterwards into a complete and beautiful representation of the flower. Riveted and clasped work, as seen in grills of all sorts, may be taken up at any time after the smith's real training is over.

The European machines now used in technical schools in India are quite beyond the means of any ordinary workman, and they suggest no substitute, so that a pupil, when he leaves the school, finds himself the worse, rather than the better, for having acquired the habit of using them, unless he can find employment in some large workshop fitted with these machines.

Such workshops give employment to only a small fraction of the whole number of workers in wood and iron, and unless primary technical instruction is adapted to the needs of the vast majority of the workmen, the hoped-for general improvement in methods of work, on which industrial progress really depends, must be indefinitely delayed. The only knowledge, therefore, which can be usefully imparted in primary technical schools is that which can be turned to practical use by the ordinary workman in any workshop, and such knowledge consists chiefly in good and expeditious processes of work which come within the resources of the artificer.

This knowledge deals, first, with the making and sharpening of hand tools, the making and testing of straight-edges, squares and plumb levels, the handling of tools in the best manner for work, accuracy in making and measuring, and the use of many simple devices for holding materials while work is being performed on them. The next stage includes the construction of such machine tools, principally of hard wood, as the artificer can make for himself and move about in a cart to temporary work, such as the joinery of new houses.

The promotion of technical education is, in all progressive countries, now regarded as one of the vital functions of the government, and such an organised system of training as is required to develop the abilities of the great body of Indian workmen can best be initiated by the government, even if the work of carrying it out devolves on local and municipal authorities. Within the present system of education are institutions which can be used for giving such technical training as I have advocated, but

we must remember that in India financial considerations at present stand in the way of educational reforms on a large scale.

It would be necessary, by way of commencement, to open a central training school for teachers, who would thus be prepared to take charge of district or village schools. Any shed with sufficient light and an earthen floor, would suffice as a building, and the work of the central school would consist, to a considerable extent, of making the machine tools for the district schools at a cost varying from one-fourth to one-tenth of such machines as are at present in use in schools and colleges. In the district schools a large proportion of the exercises in the use of tools might be performed upon firewood, the cheapest form of timber, which would lose little or nothing in value by being cut up. Each pupil, on leaving, would carry with him a sound knowledge of the arts of his work, and a sufficient familiarity with the machine tools in the school to enable him to build his own, should he require a set.

Let me repeat that education, being a means to an end, cannot be stereotyped for every class of society. There can be no doubt that the artificer in Europe finds reading an advantage in every case, and a necessity in many; but it was not always so. When books were scarce and dear in Europe, the necessity for reading and writing among artificers was not recognised.

India, in some respects, is on a level with Europe, as, for example, in postal facilities, and in transport by railway; but in many other respects her people are quite two centuries behind, and unfitted for the systems of education now recognised to be necessary in Europe. These systems will, doubtless, some day be necessary; but at present that part which will be the most immediately beneficial demands the first consideration.

It has often been observed in those parts of India where certain industries, such as stone cutting, wood carving and metal working are found in their highest state of efficiency, that the skill of the workmen is not the result of any school education, but of sound traditions of their art, handed down through many generations. In other parts, where scholastic instruction has been most popular, the supply of clerical labour soon overran the demand, with the result that tastes for a new style of life were engendered without any corresponding means for gratifying them. It has also been observed and confirmed in the annual blue book on Indian commerce, that enormous quantities of raw produce are exported from India, to be returned in a manufactured state with greatly enhanced value, because the present industrial class cannot be trusted to perform the requisite work on the material.

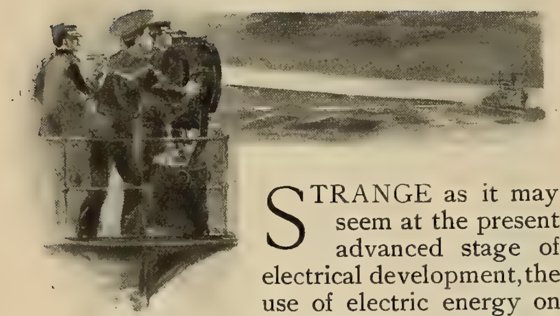
To be "made in India" at once classses ordinary merchandise as inferior even when it does not deserve depreciation, and this is due in great measure to the carelessness and unreliability of the Indian workman—and of the Indian master, who has rarely had an industrial training.

The vast wealth of India in natural products is being rapidly made known, and many of these products can be profitably utilised only at, or near, the place of origin, with the aid of suitably skilled assistance. The paper trade furnishes a striking instance of how an important industry suffers from defective technical knowledge. No country is better off with respect to fibrous material than India, and yet the methods of collecting, selecting, packing and carrying the material to the mills are so defective that the Indian manufacturers have still to depend on Sweden for their paper stuff.

The poverty of the poorer classes in India is due directly to reckless multiplication, unchecked, as it was previously, by war and famine, and indirectly to ignorance of those arts of labour by means of which the labourer's strength and intelligence can be used to the greatest profit.

ELECTRICITY ABOARD SHIP.

By James W. Kellogg.



STRANGE as it may seem at the present advanced stage of electrical development, the use of electric energy on shipboard has, until quite recently, been confined almost altogether to lighting, and the benefits of the multifarious electric power services on vessels are only now beginning to be realised.

The first installation of electric lights on shipboard was on the American steamship *Columbia*, of the Oregon Railway and Navigation Company, in 1880, since which time plants have been installed in about five hundred vessels of United States registry alone, on which the number of incandescent lights is approximately one hundred thousand, costing about $1,500,000 (£300,000). The first ship's plant was in operation for fifteen years, showing how well the system must have been worked out before commercial work was undertaken.

The plant consisted of four of the original type of Edison machines, with armatures driven by belts from engine pulleys. The practice of direct coupling to any extent was not introduced until quite recently. Even after a fairly good type of high-speed vertical engine for this purpose had been developed, the use was limited. The belted combination having given excellent results, engineers were slow to make the change to the practice which is now almost universal. At first there was a great difference between the minimum speed of a dynamo and the maximum speed of a steam engine. The designers of each reduced this until they came together, when the tendency of both was to a further reduction in the speed of the combined machines.

It is now possible to have installed on a steamer a light, compact, efficient direct-coupled generating set that will operate without noise or vibration, and continue in its good performance for as long a time as may be expected from any other piece of moving machinery on board. A good many complaints have been made at times regarding the injury to a ship's compasses, due to

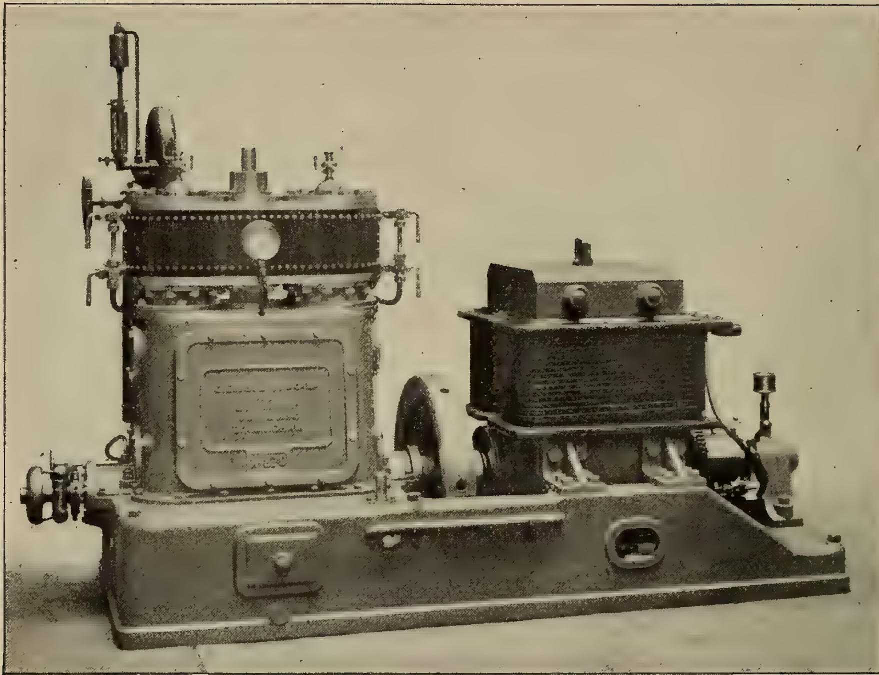
ELECTRIC HAND DRILL FOR SHIP PLATING, MADE BY MESSRS. SIEMENS BROS. & CO., LTD., LONDON.

THE DYNAMO ROOM ON BOARD THE AMERICAN SOUND STEAMER "PRISCILLA."

magnetic leakage from the dynamos and wiring conductors. In the former this leakage has been prevented by the use of a machine with a closed magnetic field, and it may be prevented in the latter by arranging the positive and negative conductors concentrically in the vicinity of the compasses.

Next in importance to the generating sets are the wiring conductors and the method of installing them, with the appliances for safety and convenience in distributing the electric current. For marine installations, especially when the vessels ply in salt water, it is essential that the insulation on the conductors should be of the highest. Thus far, rubber has been found to possess the greatest number of qualities necessary to insure this for the longest time. Government and insurance rules require that the conductors shall be of commercially pure copper, stranded for large conductors, and insulated, first, with a layer of pure Para rubber; next with a layer of vulcanised rubber containing at least 40 per cent. of pure Para rubber; and over this a layer of braid which is treated with a waterproof, and fairly fireproof, compound.

The conductors are usually laid in wooden mouldings, which are given a coat of white lead both in the grooves and on the surface. Some attempts have been made to use iron pipes in which to carry the conductors, but the sweating in the pipe is so injurious to the insulation that the practice has not been



A MARINE GENERATOR SET TURNED OUT BY MESSRS G. E. BELLISS & CO., LTD., BIRMINGHAM, ENGLAND.

ELECTRICALLY DRILLING A SHIP'S DECK PLATES WITH AN OUTFIT MADE BY MESSRS SIEMENS, BROS. & CO., LTD., LONDON.

introduced to any extent, although there is a tendency now to use iron-armoured tubing, instead of moulding, in engine and fire rooms and in places that are inaccessible, or where elaborate decorative effects are desired that would be marred by the use of moulding. If the tubes are airtight, no doubt ample protection is afforded the conductors, and in addition there is much less liability of injury from abrasion. The method of carrying wires on insulators between the beams in the holds, or where the possibility of their being interfered with is remote, is in use on some vessels and has given satisfaction.

In the United States navy the wiring appliances are mostly watertight. Cut-outs and switches are placed in metal boxes which are packed watertight by rubber gaskets and bushings. In commercial work the method of distribution is more a tendency to collect the switches and cut-outs into groups, and at these centres of distribution, as these grouping points are called, a panel is made and placed in a box which is practically fireproof and watertight. The insulating materials now used in the wiring appliances are slate, porcelain, marble or hard rubber. This is quite a step in advance of the practice of a few years ago, when wood was generally employed.

The switchboards in use to-day also show a great improvement, mechanically and electrically. The instruments are mounted on slabs of either slate or marble, with the circuits indicated by name plates. The development in the United States of the "Navy" type of switchboard has afforded some interesting problems to the designer. It was originally not considered advisable to operate the dynamos in parallel, even after it was a common practice to do so in shore plants. On the first of the new ships of the United States navy, where there were two or more dynamos, it was specified that any machine should operate on any circuit, and that it should not be possible to throw but one machine at a time on any circuit. Switchboards for as many

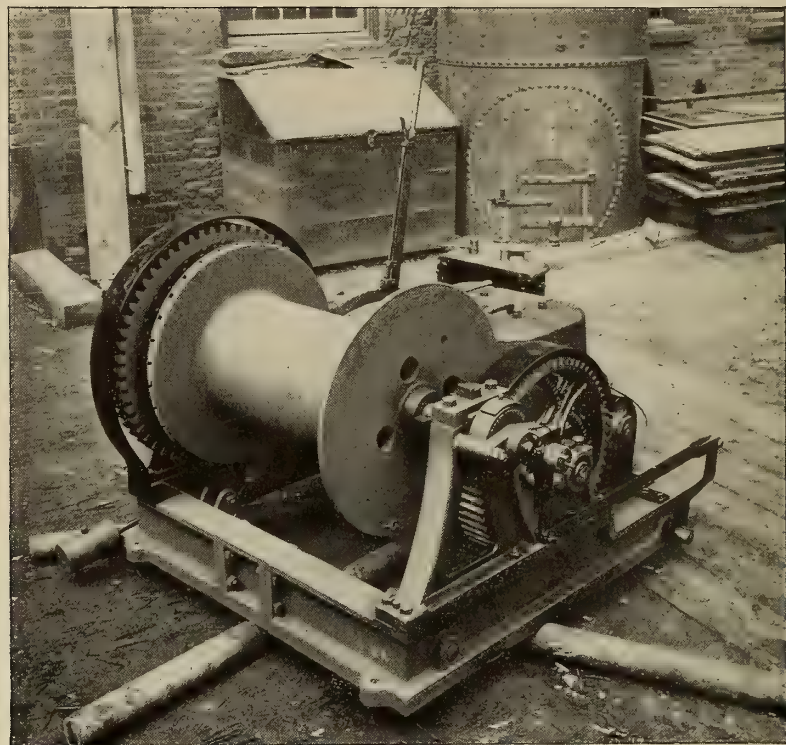
COPYRIGHTED BY MESSRS. GREGORY & CO., LONDON.

SEARCH LIGHT ON BOARD H. M. S. "MAGNIFICENT."

as four dynamos and twenty distributing circuits have been installed. Under the old specifications, a board of this kind would require a surface of about 8 feet by 5 feet. As made at the present day, the requirements are that any machine may be thrown on any circuit, or any number of machines in multiple on any circuit. This is accomplished with a switchboard about four feet square.

navy are made with electric lights, but they have not been used for this purpose to any extent on merchant ships. Signals by the Morse code are made from a lamp in a truck lantern. The current is controlled by a key in a convenient place to which the conductors are led.

Another signalling system is a modified form of the Ardois. In this, four



AN ELECTRIC DECK HOIST, MADE BY THE GENERAL ELECTRIC CO., NEW YORK.

double lanterns are suspended in the rigging, and spaced about ten feet apart. There are two lamps in each lantern, and each half of each double lantern is fitted with a Fresnel lens, the upper one red; the lower, white. A special cable supplies current to the lamps. It consists of a common return wire and eight individual conductors. These lead to a signal box which is usually placed on the ship's bridge.

The arrangement of the lamps in the lanterns admits of thirty different com-

Electric running lights are installed in such a manner as to prevent their being extinguished without giving warning to the lookout. Sometimes two lamps are burned in each lantern. The possibility of both being extinguished at once is very remote. A number of indicators have been devised in which a lamp is lighted, a bell rung, or the fall of an annunciator drop is used to show when the lamp in running light is extinguished.

Night signals in the United States

binations of red and white lamps. No two lamps are burned at the same time in any lantern, and no use is made of the difference in position of the lamps in the suspension ladder. The key-board is so constructed that by a movement of a lever to a position indicating the combination desired, contacts are made on plates connected with the lamps. A forward movement of the lever handle operates a switch in the common return. When this switch is closed, the lamps in the lanterns corresponding to the position of the lever are lighted. The signal is maintained until it is correctly answered by the display of the same signal by the ship communicated with.

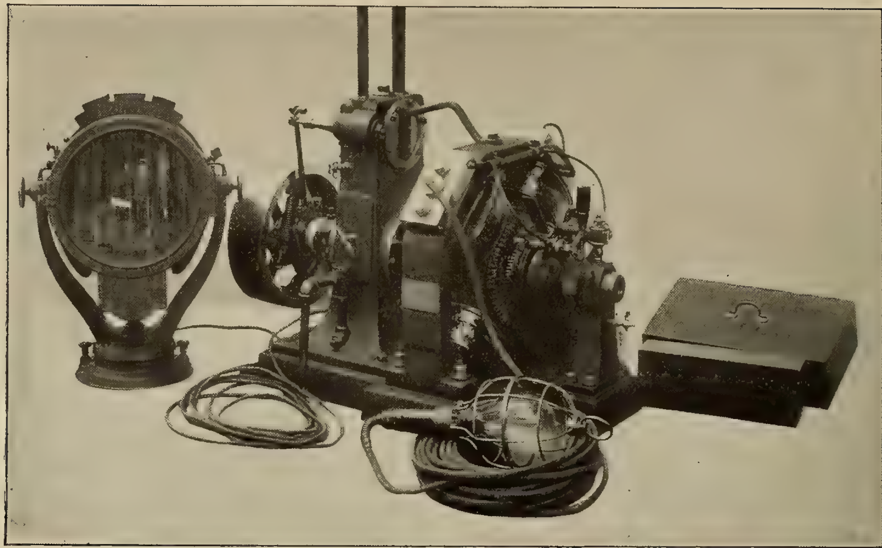
Another device which may be considered a part of the ship's lighting plant is the searchlight. This is more and more being considered an essential party of the installation. Some prejudices were originally formed against it on account of the inconsiderate use of the lights by those who were attracted by their novelty. There are many occasions when the searchlight may be of much benefit, and it is expected that an increased demand for them will result from their being desired for useful purposes rather than because of their novelty.

The Potomac river boats in the United States employ them in making landings and in picking up stakes. The immense fleet of American lake vessels have thus far made comparatively little use of them, but on account of the narrow channels that are encountered in the lake waters these would seem to promise a great field of usefulness. One of the lake captains used a projector during the past season in finding ranges at night in the Soo river, where very short turns have to be made. The courses are indicated by stakes or other marks from which the bearings are published in the Government charts. This river has always been considered a difficult one to navigate, and vessel captains would not undertake it at night, so that often a vessel would be delayed six or eight hours. By using a searchlight, however, the instances would be few when it would not be possible to follow the course with perfect safety.

During searchlight practice on some of the vessels of the United States navy, signals from one of them were under-

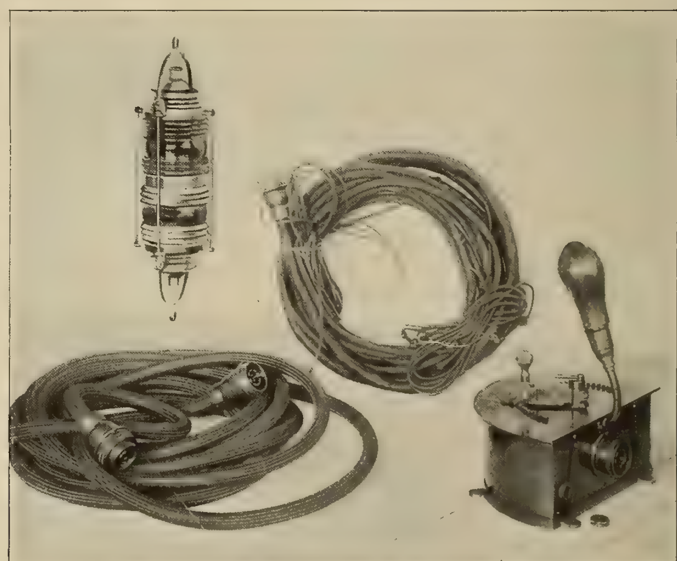
A LONG-BURNING ARC LAMP FOR MARINE USE.

stood at a distance of fifteen miles, and the flashes of the beam could be seen for twenty miles. This feature ought to be very attractive to the lake vessel owners, as it would be possible for a vessel to signal to shore from most any point in the system of Great Lakes.



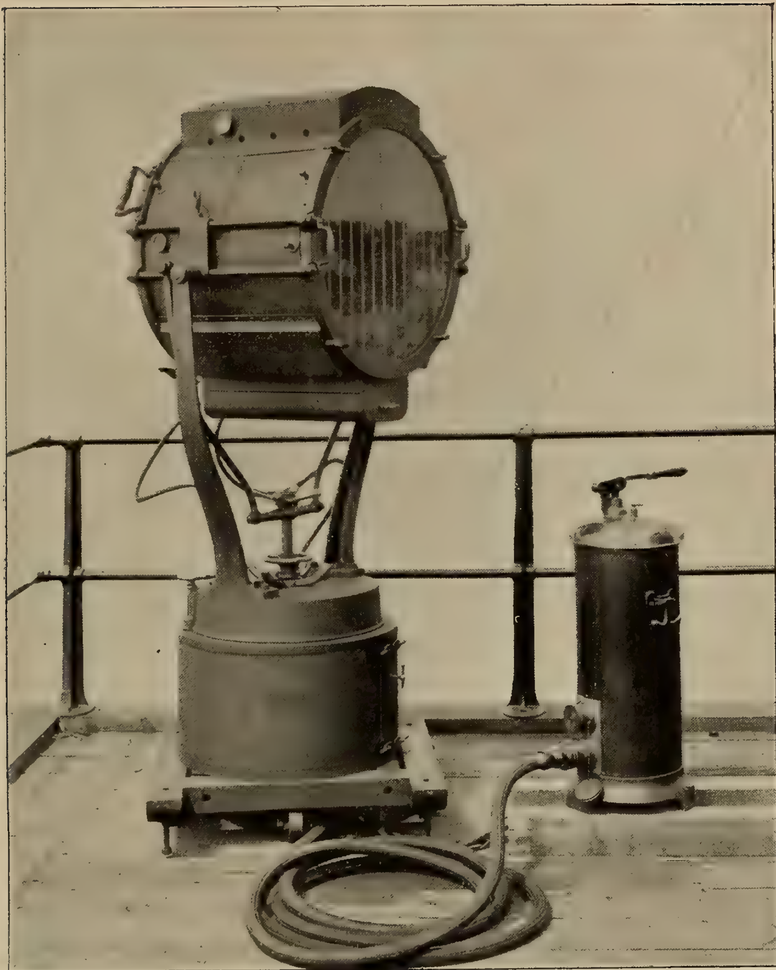
U. S. NAVY BOAT OUTFIT, CONSISTING OF ENGINE, GENERATOR, SEARCH LIGHT AND DIVER'S LAMP.

The Providence and Stonington line of American Sound steamers have used searchlights on their vessels for signalling in a fog. If the beam of light is projected vertically, a spot will be visible at the limiting distance to which the rays of light penetrate the fog. Thus, the position of the vessel from which the beam is thrown will be indicated for a much greater distance than it is possible to determine by direct observation of the vessel. Another way in which the range of light is greatly increased is by making use of the surface of the water as a reflector. If the beam is flashed onto the surface of the water at a distance which appears to the operator as the limit of visibility, the flash will be seen by the receiver at a considerably greater distance.



ELECTRIC LANTERN, KEY BOARD AND CABLE FOR NIGHT SIGNALLING AS USED IN THE U. S. NAVY.

The steamers of the Atlantic flee- make very little use of the searchlight —a fact to be regretted, as it is considered by many, well posted in the possible uses to which a light may be put at sea, to be worthy of a place in every ocean vessel. It could be so arranged



AN ELECTRICALLY CONTROLLED SEARCH LIGHT PROJECTOR, MADE BY THE GENERAL ELECTRIC CO., NEW YORK.

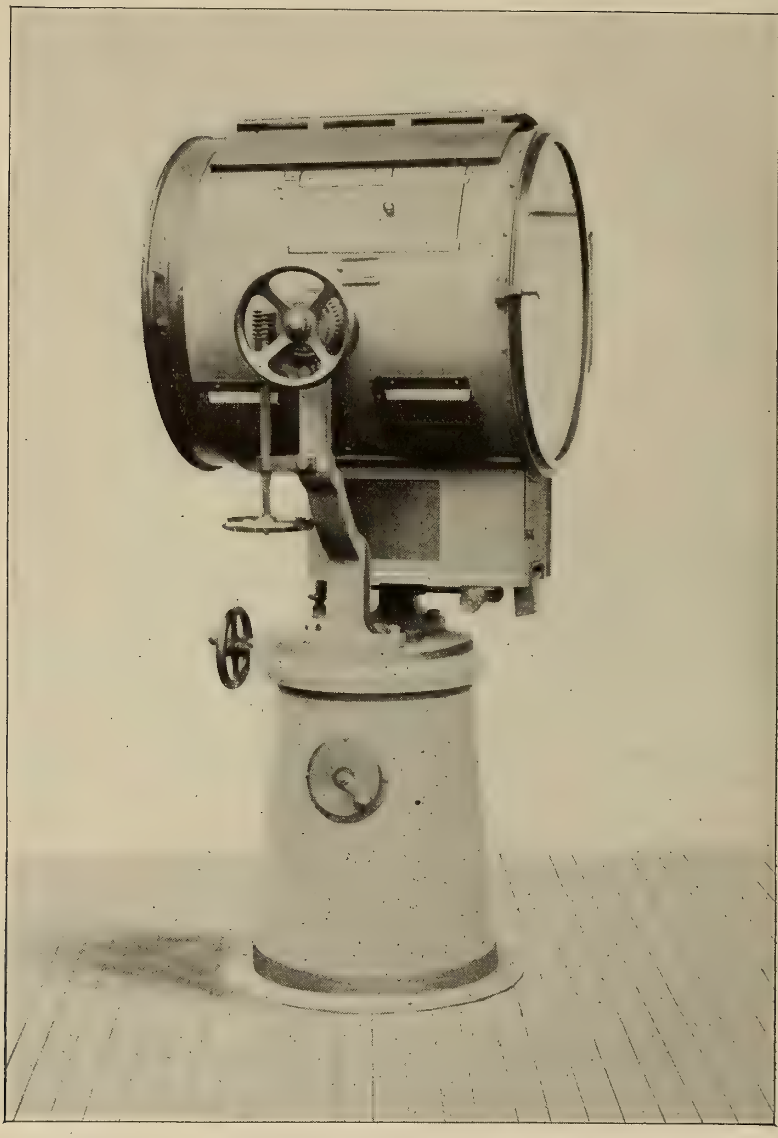
and cared for that it could be of instant benefit in cases of emergency.

With the electrically controlled projectors, it is possible for the operator to place himself in the most desirable location and to have command of the beam of light situated at any suitable place on the ship, and this by means of one handle which allows of any vertical or horizontal movement of the beam with a corresponding movement of the handle.

The use of arc lamps for general illumination on shipboard is of recent date. Since the long-burning type of lamp has been perfected, in which the arc is enclosed, and from which the light is thoroughly diffused, several installations have been made in which this type of lamp has been used. They are especially satisfactory when a strong, generally diffused light is desired, as in the holds of freight vessels. This kind of light will probably be used much more generally in ship work in the near future, the economical feature being quite marked in comparison with the incandescent light.

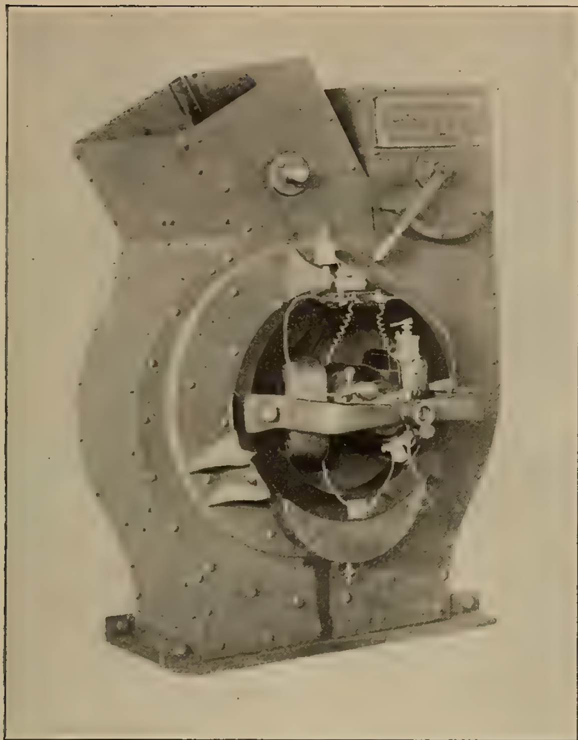
Telephone systems, controlled from central offices, are growing in use aboard

ship, and form another interesting example of the marine possibilities of electricity. Then, too, there are electric heat alarms which usually consist of a small spiral glass tube having a wire in each end and partially filled with mercury. These are placed in a battery bell circuit which is completed when the mercury is expanded so as to make connection between the two wires in the ends of the tube. They have been used to some extent in the coal bunkers of American war vessels.



A BRITISH ADMIRALTY TYPE SEARCH LIGHT PROJECTOR, MADE BY MESSRS. CLARKE, CHAPMAN & CO., LTD., GATESHEAD-ON-TYNE.

By far the most promising field, however, for the future application of electricity aboard ship is in the direction of substituting electric motors for steam and hydraulic engines which operate the



AN ELECTRICALLY DRIVEN STURTEVANT BLOWER FOR SHIP USE.

which would be capable of standing this without rendering it inoperative, and economy of operation has been very decidedly a secondary consideration. There is no doubt, for example, about the capacity of a modern ship winch to stand abuse.

Naturally, the electrical engineer is expected to enter into competition on the basis of first cost, but at present his better basis of comparison lies in the question of economy of operation, one which is very favourable for the electric motor and which will tend to be more so as the applications increase in number. Thus far it has been possible to install electric motors in only few instances, and then only one or two at a time. Operating blowers for ventilation was about the first duty for which they were introduced, and many small electric blowers, ranging

auxiliary machinery, of which so much is installed on a modern vessel. It seems strange, when one considers the number of motors in use for driving all classes of machinery on land, that so few similar applications have been made on shipboard. One very good reason for this lies in the fact that the steam auxiliaries have been designed and developed with special reference to the question of first cost to the designer and owner. Most of the auxiliary machinery on board a ship is subjected, at times, to what shore engineers would consider abuse. The tendency, therefore, has been to develop machinery

AN ELECTRIC DIVER'S LAMP.

from one-quarter to two horse-power, have been installed. The American Line steamers *St. Louis* and *St. Paul* have, each, eight motors driving fans used for heating and ventilating. In addition to the driving of blowers, electric motors are used on these vessels for operating refrigerating compressors, and for hoisting ashes and driving store-room elevators. Current for the annunciators and various call bells and gongs is supplied from a small motor-generator.

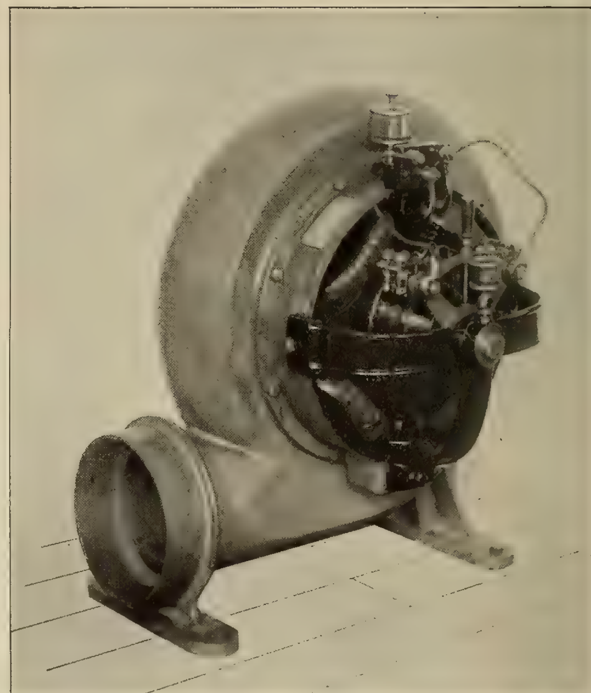
In the telemotor, an electric motor is used to operate the valve of the steam steering engine. One application of an electric motor directly to the ship's rudder has been made on a German naval vessel. A motor for operating a conveyer, used in loading coal and unloading ashes, is employed on at least one American ship, and motors, too, are in successful service on many naval vessels for hoisting ammunition.

The new steamer *Bremen*, of the North German Lloyd Line, is fitted with sixteen deck cranes, each having two motors controlled by one handle for horizontal and vertical movements. Current for operating these and also the lights is supplied from four 75 kilowatt direct-connected generating sets. These are probably the largest units ever installed aboard ship.

The first power installations on the steamers of the North German Lloyd were made by the Union Electricitäts Gesellshaft, of Berlin, the German ally of the General Electric Company, of Schenectady, N. Y., on the steamships *Darmstadt* and *Prinz Heinrich*. In these two cases, the familiar and noisy donkey engines were superseded by electrically operated winches, and it was the successful operation of these that determined the North German Lloyd to extend the use of electricity to the *Bremen*. In this case, however, in lieu of winches, a full equipment of electric cranes was installed. Four of the cranes have a capacity of 6614 pounds, and twelve of 3307 pounds, and the total swing outboard is 20 feet 6 inches.

In designing the cranes, the principal requirements specified and obtained were the following:—

The load should be lifted smoothly; the resistances should be so arranged that the various speeds of the motors should be obtained without too apparent and sudden change; the control of the different motions should be instantaneous and positive, these motions to be effected in the smallest possible space; the cranes to be compact and contain the smallest possible number of parts; the controlling mechanism to be of the simplest to suit the class of operator likely to handle them, and the electrical apparatus to be absolutely protected against changes of weather, inroads of



ELECTRICALLY DRIVEN MARINE BLOWER MADE BY THE BUFFALO FORGE CO., BUFFALO, N. Y.

THE AFTER DECK OF THE NORTH GERMAN LLOYD STEAMSHIP "BREMEN," SHOWING ELECTRIC CRANES.

dust and sea water, and to be of such a nature as to withstand rough handling.

The cranes, motor and controlling mechanism are mounted upon a circular iron platform which revolves upon a pivot. This is turned by a motor of 7 H. P. running at 700 revolutions per minute, directly coupled to a worm gear, which, in turn, meshes in a gearing bolted to the deck. The loads are raised by a 25 H. P. series motor, running at a speed of 900 revolutions, and driving a special worm gear meshing into the gear of the drum. On the gear end of the drum shaft is fitted a winch head.

The controllers resemble a double street-car controller about two feet high. The contact cylinders are operated by a special mechanism actuated by a simple handle or lever, the movements of which correspond to the movements of the load. Raising the handle raises the load; depressing the handle lowers the load, and movement of the crane to the right or left is obtained by corresponding movements of the lever. Raising and swinging movements can be effected simultaneously. So simple are these operations that the dullest stevedore can handle these cranes with ease. To give a more perfect control both motors are provided with band brakes operated by the foot. These brakes are attached to an extension of the motor shaft. The difference between the large and small cranes lies in the hoisting speed.

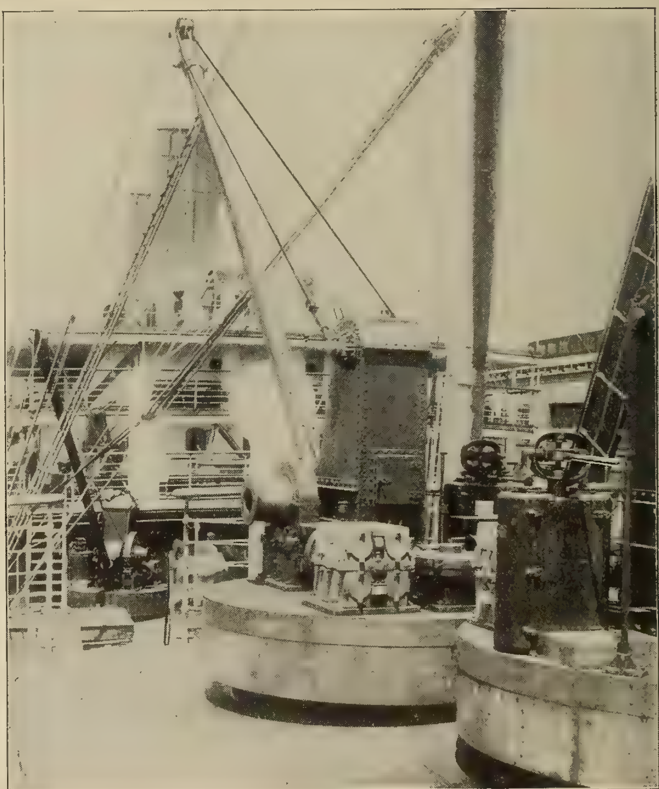
The most remarkable feature of the cranes is the absolute noiselessness of their operation. It is this feature that will recommend the electrical crane to

shipbuilders, especially those of passenger steamers in such trades as that of the Mediterranean, where loading and discharging is effected at every port.

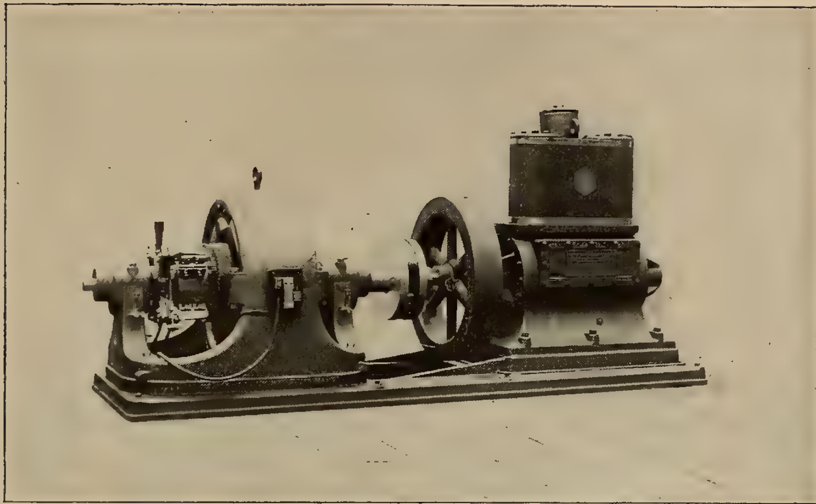
Fog signals are in use on many ships by which the whistle is blown automatically at regular intervals by means of an electric motor. The captain's gig on the United States cruiser *New York*, is an electric launch, fitted with storage batteries and motor. The use of this class of boat has not increased to any extent for several reasons, principally that of first cost. There is every reason to believe, however, that, as the batteries get cheaper, such boats will be employed quite generally, and the practical details to insure satisfactory operation under all conditions will be worked out as fully as is the case with the steam or naphtha launches to-day.

On the United States cruiser *Brooklyn* two of the 8-inch turrets are turned by electricity, and provision is made for supplying a much greater amount of electrical energy than has heretofore been contemplated. These turrets are what is known as unbalanced, and therefore a great amount of power is required to turn them when the ship is off an even keel and the desired direction of turning is opposite to that of the heel of the ship. It is assumed that it will be impossible to manipulate the guns when the roll of the vessel exceeds 10 degrees. Therefore, the maximum power required was figured on the basis of a 10-degree list. Under this condition it is estimated that about sixty horse-power will be required to turn the turret. The requirements for any system of turret turning are, as far as possible, an absolutely uniform rate of turning at any desired speed, and an instantaneous starting and stopping at will.

Both steam and hydraulic power have been applied to the turrets of ships in the United States navy, the former more extensively. The system of controlling the steam engine for this special service has been very carefully worked out, but, still, much experience is required, under all conditions of service, to enable one to train with the required degree of accuracy. In the hydraulic system, the stopping is accomplished more readily, but there are numerous other difficulties, such as keeping tight joints, and liability of freezing.



A NEAR VIEW OF ONE OF THE CRANES, SHOWING THE OPERATING HANDLE.

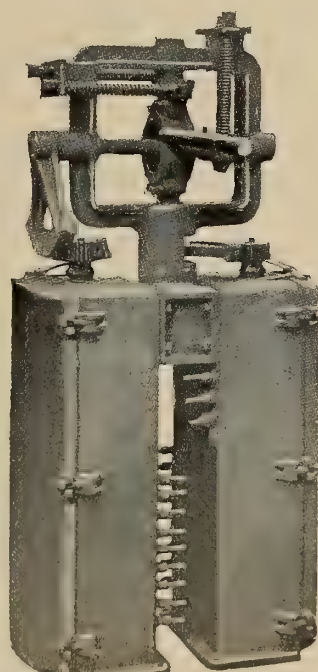


A DIRECT-CONNECTED WESTINGHOUSE ENGINE AND DYNAMO FOR MARINE SERVICE.

The tests with the electrically controlled turrets of the *Brooklyn* have shown that the requirements stated above have been more fully met than by any installation using either steam or hydraulic motors, and in view of the very satisfactory operation of the entire system as installed, it has been decided to extend the use of electricity for driving auxiliaries on the American battleships now building. Among the many additional uses to which electricity may be put are the running of ash hoists, capstans, coal hoists, boat hoists, portable pumps, winches, windlass and ice machinery.

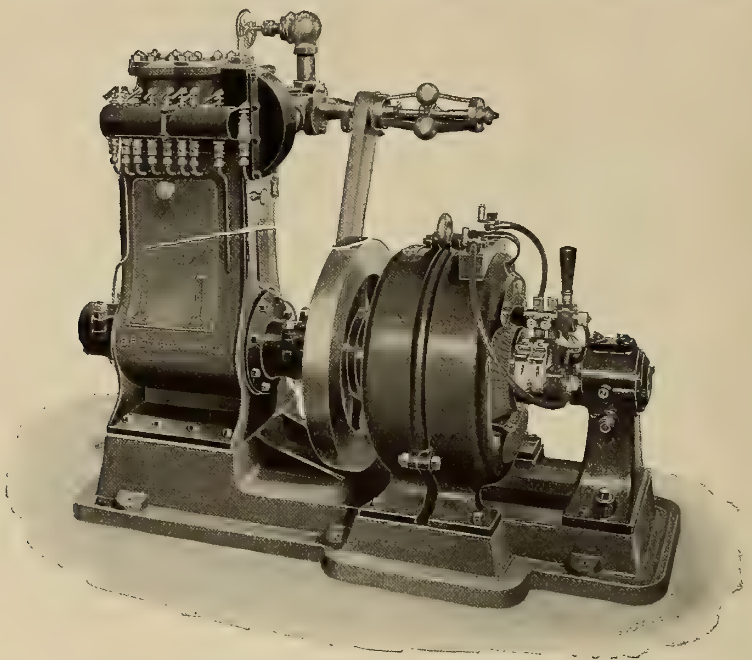
With a view to determining the relative first cost, weight and power required in a system contemplating the use of electricity, where possible in comparison with one using steam, and again one using hydraulic power, an estimate has been prepared taking as an example the United States battleship *Kearsage* now being built. This shows that for the present, steam would have a great advantage in first cost. But when the assumption of a five days' run was made, on account of economy of operation, both the weight and power required would be much less for electricity than for either steam or hydraulic power.

When the substitution of electricity for other motive powers will be undertaken by shipbuilders, the lighting plant of a vessel will not be the foremost consideration, as has been the case until now. The electric generators will be



ONE OF THE BREMEN'S CRANE CONTROLLERS WITH UNIVERSAL GEAR.

designed to furnish current in much greater quantities, and therefore the economical operation of the plant will be a very important point. The units must be large enough to provide current at all times. It is not to be expected that the introduction of electric applications can be anything but gradual, though much has been doneashore in the use of electricity in many ways which would insure the efficiency and reliability of similar applications aboard ship.



DIRECT COUPLED LUNDELL DYNAMO AND STURTEVANT ENGINE FOR MARINE USE, SUPPLIED BY THE INTERIOR CONDUIT AND INSULATION COMPANY, NEW YORK.

LEWIS NIXON.

A Biographical Sketch.

AMONG the younger men who have helped in building up the navy of the United States a prominent part has been taken, and is still being held, by Lewis Nixon.

In June, 1878, he was appointed a cadet midshipman at the United States Naval Academy by General Eppa Hunton, a member of Congress, and later, Senator from Virginia. He stood first in his class during each year of the four years' course, and was graduated first in the class of 1882. In September of 1882 he was ordered by the Navy Department to Greenwich, England, to take a special course in naval architecture, marine engineering and ordnance at the Royal Naval College, from which he was graduated in 1885 after completing the prescribed three years of study, having in the meantime been appointed an assistant naval constructor in the United States Navy, in 1884.

While abroad Mr. Nixon was sent on

several tours of general inspection by the United States Navy Department, and visited in particular the great shipbuilding, armour and ordnance works of England and France. Upon his return to the United States he was immediately ordered to duty in connection with the completion of the cruisers *Chicago* and *Boston* at Roach's Shipyard, at Chester, Pa., in this way being put in touch with the first of the vessels built for the new American Navy. From this time on he was actively engaged in duties in connection with the new vessels. He served on the staff of the Chief Constructor of the Navy as superintending constructor for the Navy at Cramp's Shipyard, and as an assistant to the constructor at the Brooklyn Navy Yard.

In 1890 he was ordered from the New York Navy Yard to the Navy Department at Washington, and was directed by Secretary B. F. Tracy to design the battleships of the *Indiana* class, under the general directions of the late Chief Constructor Wilson and the present Chief Constructor, Philip Hichborn. This work took about ninety days, and in this time the plans, specifications and general requirements of the three most powerful battleships afloat were all projected.

After the contracts for these vessels had been awarded to the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, the latter made Mr. Nixon an offer which was accepted, and he resigned from the Navy and became the superintending constructor of that great company, and continued with them while they built the *Indiana*, *Massachusetts*, *New York*, *Minneapolis*, and *Columbia*, and the *St. Louis* and *St. Paul* of the American Line, as well as numerous vessels of less importance. In 1895 Mr. Nixon leased the Crescent Shipyard at Elizabeth, N. J., and resigned his position with the Cramp Company, though he is still retained as the consulting naval architect.

Since March, 1895, Mr. Nixon has contracted, in a yard having but 400 feet of water front, for thirty vessels, and has actually finished twenty-six, among those being four vessels for South America, two steam yachts, a double-screw ferryboat, a gunboat for the United States Navy and a submarine boat. Mr. Nixon is also president of the Eophone Company, of New York, the makers of what is known as the eophone, a device for locating sound signals on water.

He is a member of the Union, Press, Richmond County Country and Seneca Clubs, of New York, the Metropolitan, and Army and Navy Clubs, of Washington, the Rittenhouse Club, of Philadelphia, and the Mattano Club of Elizabeth. He is a member of the council and executive committee of the American Society of Naval Architects and Marine Engineers and a trustee of Webb's Academy and Home for Shipbuilders, of Fordham Heights, New York City.

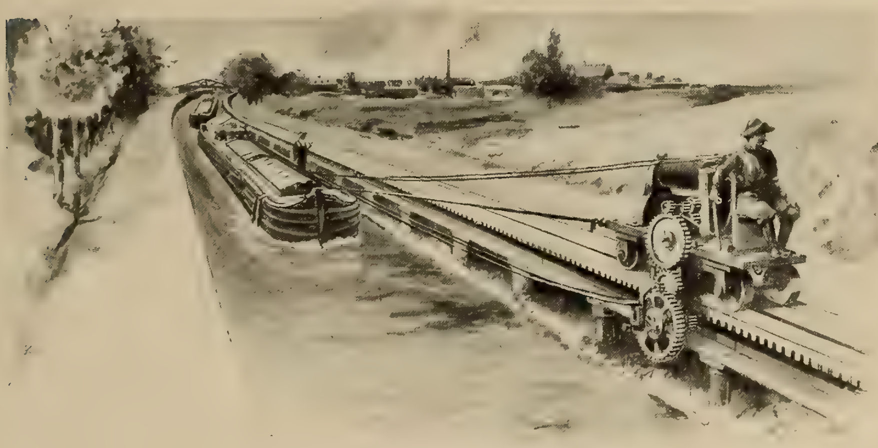
Current Topics.

THERE has been much talk of late about the storage of energy, and inventors have given time and labour to the perfecting of power storage devices; but, after all, nothing has yet been produced which can compare with the latent energy stored in solid carbon, whether we consider the bulk or weight corresponding to a given amount of work. This is best brought out by a concrete example. The altitude of Pike's Peak, in the United States, is 14,134 feet above sea level; hence, the work expended by a man weighing 150 pounds in ascending to that altitude is a little over 2,000,000 foot-pounds. The combustion of a pound of coal develops about 14,000 heat units, each one of which is equal to 778 foot-pounds of work, and if we admit that a steam engine and boiler would give us only 10 per cent. of this, we have over 1,000,000 foot-pounds as the available energy stored in a pound of coal, so that two pounds would suffice to lift a man from the level of the sea to the top of Pike's Peak. While this economy has as yet not been realised, it is no fault of the coal, for if the mere lifting of the weight is considered, the coal is quite able to perform its full share; and when the higher utilisation of the energy stored in solid carbon, which we may expect with the practical application of higher pressures and temperatures, is accomplished, even better results will follow. Some day the time may come when neither bulky boiler or engine will be needed for this transformation, and a man may, perhaps, be able to carry in his pocket a few lumps of stored energy which will tide him over every opposing obstacle.

NOTWITHSTANDING the apparently large amount of work compressed into the small bulk represented by a lump of coal, the combustion of coal under a boiler is by no means so efficient a method of generating power as is the oxidation of carbon in the human system. According to Rankine, a man can exert, when climbing a staircase or ladder, about 2,000,000 foot-pounds in a day of eight hours. An average military ration is the equivalent of about four pounds of meat, of which fully three-fourths are water and one-half of the remaining fourth only is carbon, so that half a pound of carbon, burnt in the human furnace, will do as much work as four times the quantity in the form of coal used through the medium of an engine and boiler. For the present, at least, therefore, the most econom-

ical form of stored energy which one can carry about with him is a good square meal, although its conversion into effective work may not be so pleasant an operation as that of permitting the coal to expend its own latent energy.

THE principle of the rack railroad, familiar to the mountain-climbing public as well as to the engineer, applied to an electric traction system on canals, is substantially the basis of the plan which Judge A. E. Schatz, of New York City, proposes to follow in displacing the traditional canal mule. The practical aspect of the scheme will become at once apparent from the sketch on this page. Along the bank of the canal, supported on piles, Judge Schatz proposes to lay a rail of suitable section to support and guide a small electric locomotive whose driving wheel is a spur wheel, deriving motion from the motor proper through a train of gearing, and meshing with a rack forming part of the rail. Supply and return currents to and from the motor go through conductors strung along the track level on the side opposite the rack, a double trolley being used. The rack arrangement, as in steep mountain railroad construction, of course provides for the easy climbing of the heavy-grade portions along the canal, at locks, without necessitating the use of great weight in the locomotive; in fact, the extension of the rack along the whole length of line enables the use of this principle on the level stretches as well, so that the tractive power is secured through the gearing and not through great adhesive weight. The advantages so secured are obvious, —a minimum weight of locomotive, minimum weight of track, with all that this implies in reduced cost of construction, and positive motion. The locomotive may be controlled either directly by an attendant, as shown in the sketch, or by a man on one of the boats in tow, in which latter case the stopping and starting lever and the reversing bar are worked by ropes running to the boat. The whole arrangement seems simplicity itself. Nothing is proposed that experience in other, though similar, lines has not shown to be perfectly practicable, and we may, therefore, find in this one of the coming methods of mechanical canal haulage, with the time-honoured canal mule relegated to the same position that the trolley system on tramway lines has prepared for the once prominent car horse.



AN ELECTRIC CANAL BOAT TRACTION SYSTEM.

ONE of the most instructive features of the Royal Naval Review at Spithead during the late Jubilee ceremonies in Great Britain was the presence of foreign warships. The fifteen miles of vessels of various kinds were a grand display of British naval power,—one which no other power in the world can imitate at the present time, or for some years to come. But some of the foreign ships are admitted by British officers to be formidable foes, and only wanting in numbers to successfully dispute the "command of the sea." The United States armoured cruiser *Brooklyn* called forth great admiration, and was eagerly compared with the *Terrible* and the *Powerful*, the latest additions to the British Navy, and which are supposed to be the most potent instruments of their kind which Whitehall can, at present, devise. They have protective steel decks from 3 to 6 inches thick, 6-inch bases of turntables for their heavy guns; casements, 2 to 6 inches, for their 6-inch, quick-firing guns, and shields for other guns. The *Brooklyn* has all this protection, and, in addition, a steel partial belt, 8 feet broad, whilst her barbettes have armour ranging from 6½ to 15 inches in thickness Again, in heavy armament the *Brooklyn* has a decided advantage over the British cruisers, as she carries eight 8 inch breech-loaders, against their two 9.2-inch breech-loaders. The additional complement of lighter guns possessed by the latter vessels will not restore the average, more particularly in view of the partial belt which affords additional security to the United States vessel. Light, quick-firing guns and Maxims are useless against such armour, unless, perchance, high explosives may aid them, and at present the Whitehall and Horse Guard authorities taboo high pressures and high explosives for their guns,—they reserve them for their marine boilers and engine cylinders.

THE Russian *Rossiya* and *Pothuan* also elicited great admiration. The armament of the latter vessel is not so heavy as that of the *Brooklyn*, and, indeed, hardly equals that of the *Terrible*, as she carries only two 7.48-inch breech-loaders, and ten 5.46-inch quick-firers, against the two 9.2-inch breech-loaders and twelve 6-inch quick-firers of the latter vessel. She has, however, a complete belt of 2 to 3.9-inch steel in addition to her protected deck, and British tars, however brave they may be, are sufficiently human to appreciate the sense of security which armour gives when shells are flying about.

THE subject of electrical transmission of power in machine shops proved an interesting feature of the discussions at a recent convention of the American Society of Mechanical Engineers, and apart from the immediate subject involved, it brought out many interesting facts in relation to power transmission. The causes for the large proportion of power wasted in existing transmissions are due to conditions which cannot always be foreseen, and thoroughly capable engineers are often obliged to do things against their better judgment, for reasons which are beyond their own control. It is only occasionally that a large manufacturing establishment with complete power and transmission plant is planned from the first. Usually, a small shop is started, with economy in first cost as the controlling influence. As the concern prospers, additional buildings are erected, and frequently the question of power transmission is not considered at all until the machinery is to be put in, and then it is found that many awkward problems present themselves. Establishments, as a rule, are not planned at all, but *grow*, and grow along the lines of least commercial resistance; so that it is small wonder that we see quarter-turn belts, heavy mule posts, gearing, line shafts, etc., put in with the evident purpose to "get there" at all cost, efficiency being altogether a secondary consideration.

FOR such conditions, and they are the conditions which one meets everywhere, electric transmission has many

advantages. The new pattern shop may be on the other side of the street, or the foundry quite out of line with the machine shop, and it makes no manner of difference about getting the power just where it is wanted; while if the question of rearrangement of tools or plant comes up, there is nothing in the way of power transmission which interferes in the slightest degree with the putting of a machine just where it will do the best work at the least cost,—the handy wire carries the current to the work, and the transmission becomes a servant, not a master. Under these conditions, the question of the electrical efficiency is only one element in the problem, and it is the total efficiency of the entire plant which should rule. The part which badly arranged machinery bears to the total efficiency,—or lack of efficiency,—is often overlooked in considering the question of shop economy, but it continues to exist, nevertheless, and often makes itself felt on the wrong side of the balance sheet.

An excellent example of the way in which the introduction of new machines plays havoc with previously planned power transmissions may be found in saw-mill practice. In the great lumber country of the American Northwest the mills are carefully planned for the most efficient continuous service. Steam economy is a minor consideration, as more wood waste is produced than can be burned under the boilers in any case; but capacity for continuous output is a prime essential. In order to avoid the obstructions inevitably accompanying overhead belting, it is usual to place the shafting beneath the mill floor, and all the machines are so arranged that there shall be no interruption to continuous flow of material, from the entering logs at the one end to the finsihed lumber at the other. Now the main driving pulley of a band saw-mill is at right angles to that of a circular mill for the same position of carriage, and when in many of these great establishments band mills were substituted for circular mills a general transformation in the transmission plant in the basement became necessary. Frequently large bevel gears had to be introduced, with all that this implies in the way of heavy pillow-blocks, piers, etc., while in other cases it was found advisable to put in independent engines to get the power to the new saw-mill. Had all this been done by independent electric motors, none of this expense need have been incurred, and the question of transmission would have required scarcely a thought. Electrical driving has scarcely found its applications as yet in the lumber country, but in view of the success which has been attained in other directions it seems excellent for just such locations.

Apropos of basement floors for machine shops, Professor Sweet, in a note prepared for the recent meeting of the American Society of Mechanical Engineers, said that where the ground to be floored is solid, only such a depth of filling is necessary as that required to distribute a concentrated load over large enough area, so that a hole will not be punched through what constitutes the floor. Concrete, if of the best quality, may be as good as anything, and the necessary thickness would depend on the weight of the loads which it has to support. A layer of thin flat stone, or two layers, bedded in concrete, and then a thin coating of concrete to give the full depth of, say, 6 inches, is better than 6 inches of concrete, however good. To cut off moisture which may be expected, a coat of asphalt is best. Quicklime would be effectual, but with an unmatched floor the lime would sift through the cracks. A layer of two-inch plank is better than scantlings buried in the cement, as it better distributes the load, and joints in the top floor can come anywhere. Professor Sweet has determined by experience that the expected in this case does not happen; the floor does not spring up and down. The top flooring is best of only ⅞-inch stuff, 5½ inches or less in width. When the thin top floor is worn through in places and

needs repairing, the hole or depression is only ⅞-inch deep, whereas with thicker top flooring it is deeper. At the works of John Lang & Son, of Johnstown, Scotland, the shop floor is wholly of iron chips, and is a solid, fairly good floor,—not as clean as a wood floor, but one that would answer well in a basement. The cost of such a floor would depend on the market value of chips. It is cheap to put down and the night watchman can keep it in repair.

EVER since compressed air spraying nozzles were used in connection with the Chicago World's Fair buildings in 1893 for covering large surfaces with paint, the practical value of devices of

A CAR PAINTING MACHINE.

this class has grown in appreciation until, at the present time, painting machines have become fairly common articles of purchase, and, for some purposes, have almost altogether supplanted the place of the conventional paint brush. Railroad companies were quick to realise how much time and labour could be saved by using spraying nozzles, and long before the Chicago experiment numbers of them were in operation in different railroad shops and yards, painting shop walls and railway equipment generally with results of a most satisfactory kind. The outfits, however, were all of the "home-made" variety. Each user made his own machine from whatever available shop material he had, and it is reasonable to presume that the devices of those days lacked the efficiency and refinement of operation which is expected and obtained in the machines now regularly offered for sale. Of these there are probably half-a-dozen makes on both sides of the Atlantic.

ONE of the latest American varieties is shown in the accompanying sketch, particulars of it having been given by Mr. D. W. Smith, of Wellsville, Ohio, who has used it extensively for painting railroad car bodies. The spray is fan-shaped, and when the nozzle is held at the proper distance from the surface to be painted,—about 12 inches,—it will cover a width of about 14 inches. A regulating valve affords control over the flow of paint and the operator can quickly vary the amount by slightly turning a thumb screw. There is also an air regulating valve, fitted to the paint reservoir, which latter holds about 10 gallons, the air pressure ranging from about 40 to 65 pounds. A ½-inch air hose is attached to the air valve and connects with a compressor, while the nozzle is connected to the reservoir with a ⅜-inch paint and a ⅜-inch air hose. Valves also are provided for stirring the paint with air and for blowing the paint out of both hose and nozzle when desired. Mr. Smith says that with this machine the body and roof of a 34-foot box car can be given its first coat in 24 minutes, its second coat in 20 minutes, and that a gondola car body, with 44-inch sides, can be painted in 10 minutes for each coat. He also states that the apparatus uses less material than painting

by hand, and that the operator, having complete control of the flow of paint, can apply a heavy or light coat as desired.

THE discovery of the X-rays has suggested to Prof. Elihu Thomson a fresh possibility of transmuting metals. In a recent paper the distinguished electrician points out that our knowledge of the elementary bodies and their chemical combinations has hitherto been limited by ranges of temperature not in any case exceeding 5000°. In a Crooke's tube, however, with air rarified to a tension of one-millionth of an atmosphere, the molecular bombardment of the residual air is sufficient to bring the platinum electrodes to a bright red heat in a few seconds. Why not, therefore, suggests Prof. Thomson, adapt this method of producing very high temperatures to experiments on elementary bodies? A steel retort, lined with magnesia, ought to withstand the long-continued passage of electrical currents of very high voltage, and the effect of these might give us hitherto undreamed-of changes in bodies now regarded as elementary.

TRUE it is that the history of alchemists and alchemy, with its record of vain seekings for the philosopher's stone and the transmutations of the baser metals into gold, has had the effect of casting the cloak of skepticism over all modern experiments which have dealt with the transmutation of metals. Yet on *à priori* grounds, the chances of demonstrating the identity of all the elementary bodies seems much greater than those of ascertaining the properties of the ether or the cause of gravitation, because as long as each elementary body is distinguished from every other by a specific and unchanging atomic weight, the material problem of what would happen if the atomic weight of a body could be altered by heat or pressure, remains to be solved. If the atomic weight of carbon, for example, should be changed by experiment from 12 to 1, would the transformed body retain the properties of carbon or would it assume those of hydrogen? If we assume that matter is material—an hypothesis which many philosophers refuse to accept— have we any greater reason for believing in its ultimate differentiation into separate elements than the experimentalists of a century ago had in believing in the ultimate differentiation of forces? Yet Joules, in the middle of the present century, established the quantivalence of forces once for all. It must not be forgotten that Davy and Dumas, both in the world's front rank of experimental chemists, believed that the transmutation of the elementary bodies would some day be demonstrated. And, looking at the recent magnificent discoveries of Moissan with the electric arc furnace in the practically unknown region of metallic carbides, are we not justified in anticipating in the near future some fundamental advances in the science of chemistry?

THE increasing weight of locomotives in the United States has created a serious problem for those who have charge of the permanent way over which these engines run. The Southern Railway, for example, has at present in course of erection at the Richmond Locomotive and Machine Works, in Virginia, two sister engines of unusual capacity. The weight of one of these engines is 150,000 pounds, of which no less than 131,000 are placed on the driving wheels. This weight is distributed over six wheels coupled, each 72 inches in diameter, with a base of 14 feet 7 inches. The cylinders are 21 x 28 inches and the working pressure 200 pounds to the square inch, while the tractive power is 34,063 pounds. One should imagine from the 6-foot drivers and other dimensions that these engines are intended for handling exceptionally heavy passenger trains at pretty high rates of speed, and they, therefore, at once raise the serious question of wear and tear of track under such heavy moving loads. Six-wheel coupled freight

engines, moving at a maximum speed of 25 miles an hour, play havoc enough with the permanent way, the combined grinding and pounding of their extended rigid wheel base loosening spikes, ties and ballast to a far greater extent than the similar action of many more four-wheel coupled engines. The difficulty of the engineer in charge of the permanent way, in such cases, is that he cannot separate the destructive effect of one class of engines from that of any other class. The state of his track at any given moment is the resultant of all the trains which have passed over it, and he cannot, except inferentially, apportion the blame.

In the United States the question of the weight of locomotives is generally settled without paying much attention to the protests of the engineer in charge of the track, except to get his assurance that his bridges are strong enough to carry the increased weight. In Europe, however, and especially in England, the engineer in charge of the permanent way is almost invariably a much more important personage than the locomotive superintendent, and his veto is often successfully interposed when it is proposed to build engines heavier than he considers good for his tracks and roadbed. It is probably due to this wise conservatism that the tracks of the main line of the London and Northwestern Railway are always in such magnificent condition with apparently so little effort. Thus the celebrated "Lady of the Lake" class of locomotives which have hauled the Irish and Scotch mail trains for so many years weighed in their original form only a little over 60,000 pounds in working order. These engines had single driving wheels 7½ feet in diameter, with 16 x 24-inch cylinders. Even as some of them have been rebuilt during the past few years, they now weigh in working order only slightly over 65,000, while the heaviest express passenger engine on the London and Northwestern system weighs 101,920, or very little more than two-thirds the weight of the locomotives now in course of erection for the Southern Railway in the United States. Yet the London and Northwestern runs through a tract of country ten times as populous and ten times as wealthy as the Southern Railway does. President Charles P. Clark, of the New York, New Haven and Hartford Railroad, when asked what had struck him most forcibly during his recent trip to Europe, replied that he came home with the conviction that both engines and trains in the United States were generally heavier than they need be, and that so far as he was concerned he would do his best to devise some plan of lightening the dead load of engines and trains on the railway with which he was connected. The advantages of such a reform, wherever practicable, on American railways, in preserving the track in good condition, is too obvious to require comment.

Admiral P. H. Colomb, of the British Navy, recently came to the conclusion that huge iron-clad warships are a waste of money, because a fleet of such ships may be attacked and destroyed in detail by torpedoes. He advocates, therefore, the construction of comparatively large sea-going torpedo vessels to take the place of battleships as England's first line of defence against foreign invasion. Great weight is necessarily attached to Admiral Colomb's views because he is recognised as one of the ablest of living naval strategists, and also because he has always been an original and daring thinker in matters pertaining to naval warfare. What makes the admiral's advocacy of torpedo vessels more remarkable is the fact that a few years ago he was strongly in favour of the supremacy of battleships as against torpedo attack. He frankly pleads guilty to this charge, but reasons that under Sir William Henry White, and others, battleships have attained the limit of possible perfection, and that, therefore, reasoning by analogy, they are on the point of being superseded by some new implement of destructive attack.

To illustrate Admiral Colomb's position, it may be pointed out that the heavily armed wedge-shaped phalanx of the Greeks was ultimately defeated by the deep front line Macedonian formation. This, in its turn, gave way to the more mobile and better disciplined Roman legion, which, in due time, fell before armoured knights on horseback. The deadly aim of the English archers at Crecy, followed by the general introduction of firearms, proved that personal armour was more a burden than a defence. In our own day close infantry formation, firing at close range and culminating in the bayonet charge, has been discarded for open ranks and long range firing. There is thus a perfect evolution in land battles from heavily armoured and comparatively immobile units of large size to much more numerous and more mobile units, each presenting a smaller target for attack. The British naval authorities have always had this analogy in mind ever since the *Monitor* fought the *Merrimac* and revolutionised sea fighting. But one departmental committee after another, composed of the ablest men in the service, has reported in favour of continuing the construction of sea-going battleships. Yet, as a practical result of the work of these committees, we have the first-class battleship of to-day. This class of ship may be described as an armoured citadel on an unarmoured raft, in contradistinction to the earlier types which were armoured pretty evenly all over above water line without special reference to the protection of the guns.

One of the most interesting engineering features of the past few months was the motor car competition arranged for by *The Engineer*, of London, about two years ago and finally held on the last day of May, this year. Prizes to the amount of 1000 guineas had been offered; a thoroughly competent committee of judges had been secured; and with the earliest days of the announcement entries had been made, amounting, in the end, to seventy-two, so that there was, at one time, an excellent prospect of results of decided value. As the day of the trial approached, however, withdrawals began to come in, until finally, on the day of the trial, only five vehicles were ready to take part in the competition, and of these, none, in the opinion of the judges, could be conscientiously awarded a prize under the terms of the contest. To every one interested in self-propelled road vehicles the result must have been disheartening, though in one respect, perhaps, it has been satisfactory. As *The Engineer* put it, the competition "has cleared the air. It has placed the world in possession of facts concerning the motor car industry in this country (Great Britain). There is at present no such industry. There is no such thing as a thoroughly satisfactory self-propelled vehicle." It is worth noting that at almost the same time another motor carriage competition was held at Crewe, under the auspices of the Royal Agricultural Society, and the result there was practically the same. Only three entries were made for the prizes offered, and only one of the vehicles appeared on the day of the trial. Possibly some explanation for these poor showings may be found in the fact that, in *The Engineer's* competition at least, comparatively little encouragement was given to the makers of carriages driven by gasoline engines. More importance is attached to the danger element in such motors in Great Britain than in other countries, in France, for example, and in America, where motors of this class have given some of the best known results in the propulsion of common road vehicles, though, true enough, the latest developments have been along the electric storage battery line. After all, however, the outcome of the British competitions portrays pretty fairly the present state of the art of motor carriage building everywhere. None of the designs have gone beyond the experimental stage, and the horseless vehicle, in the generally accepted sense of the term, will probably be far from universal for some time to come.

The engineer-in-chief of the British Navy has been created a K.C.B. Sir Albert John Durston has well deserved the personal honour, and it is hoped that he may enjoy it for long years. The promotion in the Order of the Bath confers on him no further dignity or authority at the Admiralty, nor will he be assisted in promoting the professional advancement of the engineering branch by being "Sir Knight." It is, however, a step in the right direction to find that being a naval engineer is not an absolute bar to such dignity.

The most interesting paper at the recent meeting of the Institute of Naval Architects was that by Sir Edward James Reed, K.C.B., on the mathematical theory of naval architecture. Probably no one in England has done more to advance the application of mathematical principles to practical ship designing and building than the author of the paper, not only by his own investigations, but also by the influence he exercised on others. The disastrous end of the *Captain* and the capsizing of the *Daphne* years ago were both brought at the time under his immediate enquiry, and these calamities must have confirmed his conviction, if confirmation were needed, that rule of thumb computations are not safe with the modern complexity of weights and conditions in large steamers. None of the members were better qualified than Sir Edward Reed to treat the subject. Brought up in the unscientific atmosphere of the old Portsmouth Dockyard, he broke away from its enervating influences when merely an apprentice, and now, in his later years, he remains pre-eminent as a scientist. He has been the leader of the evolution he so eloquently records.

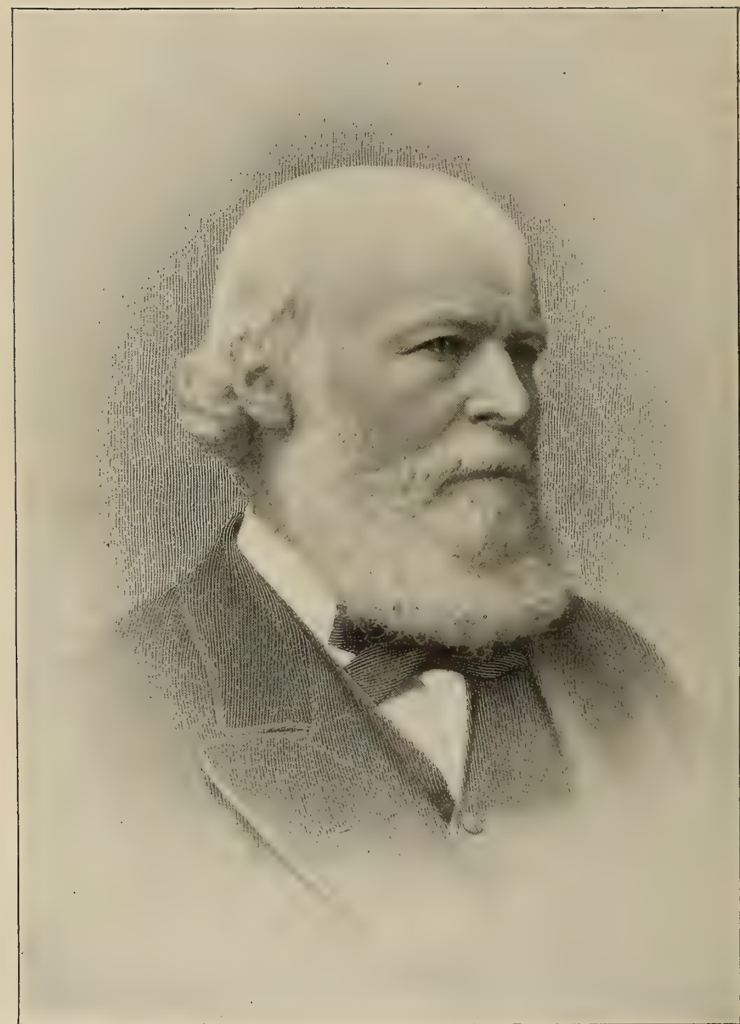
Mr. Milton, of Lloyd's Registry, at the same meeting drew attention to the difficulties under which engineers of ocean tramps labour in maintaining the machinery of their ships in good order. These hard-running vessels have often to work in ballast, when, as he pertinently described them, they resemble so many bladders floating on the water with the screws only partially immersed. In this condition every turn of the propeller shaft causes four blows of the screw on the water, with a resultant shaking of both ship and machinery which it is more pleasant to imagine than feel. The price of these tramps is cut so fine by the competition between builders that there is little room for expenditure on either design or precautionary fittings; but the cost of repairs and renewals on them is very great, and owners will probably find an advantage in paying a little higher price in the first instance, if they can thereby reduce the subsequent annual expenditure.

Cassier's Magazine–October, 1897.

CONTENTS.

$3.00 per year. 25 cents per number. Entered at the New York Post Office as second-class matter.
 Published Monthly.

☞ Index to Advertisements will be found on page 10.



FROM A COPYRIGHTED PHOTOGRAPH BY ELLIOTT & FRY, LONDON.

Sir Lowthian Bell

CASSIER'S MAGAZINE.

VOL. XII. OCTOBER, 1897. No. 6.

TURBINE BUILDING IN SWITZERLAND.

By Alph. Steiger.

THE INTAKE FOR THE SIHL POWER HOUSE.

THE many interesting descriptions of water power plants which have appeared, from time to time, in the pages of CASSIER'S MAGAZINE indicate the increasing attention which is being paid to water power all over the world. Most of the articles have described water power plants erected for the purpose of generating electricity either in America or in Switzerland, showing that, at present, these two countries develop the greatest activity in turning their riches in water power to useful account.

An American engineer who recently visited Switzerland designated that

TRANSFORMER HOUSE AND TOWER FOR CARRYING WIRES ACROSS A RAILROAD TRACK. THE SIHL POWER PLANT.

country as the electrical centre of Europe, which may also imply that it is as well the centre of Europe for hydraulic power. I hope I shall, therefore, not be accused of improper national pride if I put Switzerland at the head of other European countries for water power installations and turbine building, and compare, for the purpose of this article, water power installations and the method of turbine building of that country with those of America.

While both countries can boast of numerous water powers and remarkable waterfalls, and of a population, intelligent and enterprising, ready to make the best possible use of the forces with which nature has provided them, it is remarkable to notice the wide difference in the types and construction of turbines and the methods of building them in the two countries.

The difference, briefly stated, is this, that American turbines are almost exclusively wheels with inward flow and axial discharge, while European

THE SIHL PLANT. ARTIFICIAL LAKE WITH DAM AND OVERFLOW.

turbine builders prefer parallel flow wheels. Further, American turbines are built in fixed standard sizes whatever the conditions under which they are destined to work may be, whereas European engineers design their turbines to suit the local conditions and special requirements of each case.

One must review the history of turbines to find a plausible explanation of the reason why most of the American turbines are of the inward flow type. The Borda turbine, probably the first turbine in existence, is the origin of the turbine with parallel flow, while Segner's or Whitelaw's wheel must be considered the prototype of the other form. Fourneyron was the first to improve the reaction turbine and to succeed in producing a wheel of high efficiency. He may, therefore, well be considered the father of modern turbine building, and his design is even now sometimes adopted, as, for instance, in the great Niagara water power plant. It is a radial flow turbine with outward discharge.

The merit of having further improved this radial flow type of turbine belongs undoubtedly to the late James B. Francis, whose researches in the hydraulic branch of engineering justly put him in the front rank of eminent American engineers. Francis reversed the flow in the Fourneyron turbine and made his wheel an inward flow turbine, thereby avoiding some hydraulic losses characteristic of outward flow turbines. To the good results which were obtained from his turbine is, doubtless, due their general adoption in the country of its invention.

The further development of inward

TOWER FOR ESCAPE OF AIR FROM MAIN PIPE.

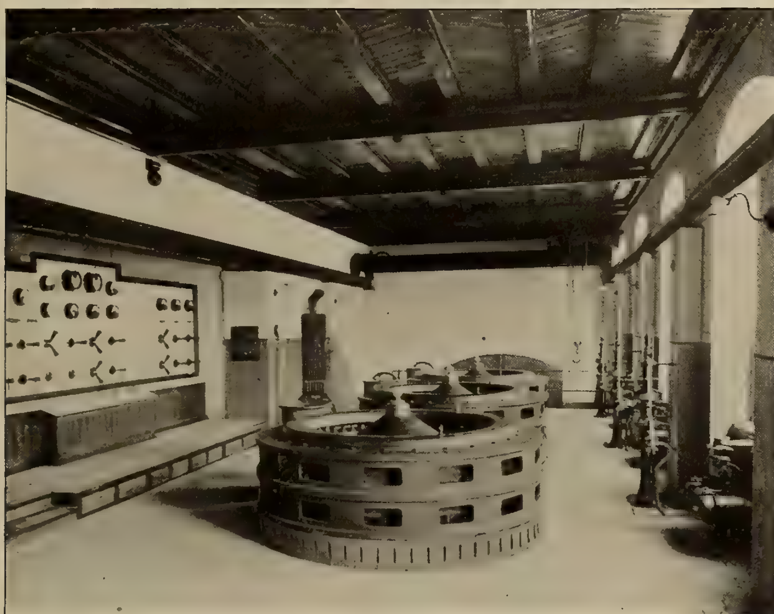
THE POWER HOUSE ON THE RIVER SIHL.

flow turbines in America has taken place more on purely empirical than scientific lines. The axial discharge from the vanes of the turbine wheel is an addition to the inward flow turbine pure and simple, intended to increase the efficiency. The tendency of producing turbines at low prices has led to the adoption of fixed standard sizes, mostly of small diameter in relation to the volume of water to be utilised, and in proportions not always in accordance with certain hydraulic principles which the European turbine builder considers essential for good efficiency.

Such a manner of building turbines in a purely empirical way,—by the cut and try process,—of necessity called for a public testing station, like that at Holyoke in Massachusetts.

Remarkably high results are reported to have been obtained there from certain turbines. Although there are no reasons why a radial inward flow turbine, if properly designed, should not give as high an efficiency as a good axial flow turbine, I cannot suppress some doubts as to the correctness of the exceptionally high results claimed for some of these wheels, and my doubts are based not only on theoretical grounds, but on my own observation of such turbines working in Europe, and on some independent tests which have been made.

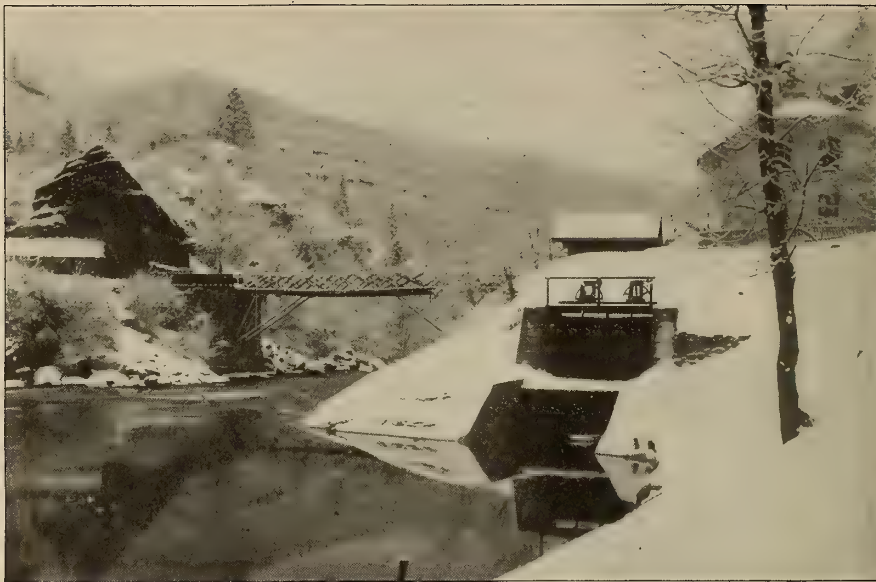
But whatever the efficiency of these turbines at full gate may be, the tests show a considerable decrease of efficiency at part gate, especially at half gate and less than half gate. The explanation of this fact is found in the immense volume and the never-failing supply of water in those places in America where water power has hitherto been utilised.



THE DYNAMO ROOM OF THE SIHL PLANT.

It is but natural that in a new world, where the development of industries went hand-in-hand with the construction of railways, the water powers, with an abundant and regular supply of water would, in the first instance, be utilised where great economy is of secondary importance. The task of the turbine builder under such favourable conditions is rendered easy.

We are not in the same fortunate



WATER INTAKE FOR THE TURBINES OF THE ELECTRIC LIGHT AND POWER PLANT "LA GOULE."

position in Europe and especially not in Switzerland. Here industries are older than railways, and had to take hold of water power under whatever conditions it could be found in accessible places. The water supply in mountainous districts, where no natural or artificial lakes are available, is very irregular and unreliable, while an accumulation of water in the flat parts of a country, where it cannot flow away as freely as it comes down the slopes of hills and mountains, reduces the fall at times of rain or melting of snow.

The problem of obtaining constant power under such different and varying conditions is particularly fascinating for a turbine builder and its solution is of the utmost importance in a country without coal mines and with heavy railway rates. This, to a great extent, explains why Swiss turbine builders have developed the art of turbine building in a manner quite different from that in America. But apart from this, the system adopted on the European continent for the education of engineers gravitates so much to the scientific side that the application of theory could not fail to play an important part in the development of our turbines, and, it must be admitted, in perhaps no other machine is sound theory more properly applied than in a turbine.

Swiss engineers had such a variety of conditions of water powers to deal with that it is not surprising that turbines, built on absolutely different principles, were developed simultaneously,—some to utilise the high falls, with small and varying water supply, of the mountainous districts, others to get the best of the lower, but irregular, falls in the lower and flatter country, with more abundant, but, to a certain extent, also varying water supplies. Still, it would be erroneous to believe that the one class of turbines, which we call impulse wheels, intended, in the first instance, to utilise high falls, could not also be of good service under low falls; indeed, one of the early instances where the impulse principle was advantageously applied was for a very low fall.

The well-known Poncelet waterwheel, which is nothing but an impulse wheel pure and simple, though not different from an ordinary undershot wheel except in the matter of its curved floats, has, perhaps, not received the recogni-

tion which it deserved at a time when no better motor for corresponding conditions was in the market.

The Poncelet wheel, built to suit higher falls with small water supplies, and with the improvements applied by Girard to his turbines, is the prototype of the modern design known to the readers of CASSIER'S MAGAZINE as the Pelton wheel. I believe the American Pelton wheel was introduced to utilise the high falls in mining districts for driving stamps and ore crushers working in unprotected places. It is, consequently, constructed in the simplest manner possible, still giving, which of course is essential, a fair efficiency. The corresponding European wheel, on the contrary, was first introduced for very delicate conditions, namely, to utilise high pressure water supplies of towns for the distribution of power among small factories. That under such apposite conditions the construction of the motor should have received more careful attention than a wheel for a mine does not need to be pointed out. Very carefully executed brake tests, when the water was collected in tanks, and could, therefore, be measured with absolute accuracy, have shown that some of these European Pelton wheels have given 83 per cent. efficiency.

The advantage of turbines of the Pelton wheel type, *i.e.*, with horizontal shaft, allowing a direct drive of machinery by belt or rope, or by coupling the armature spindle of a dynamo directly to the shaft of the turbine is undeniable, and has made this a favourite type with electrical engineers; still, for moderate falls, or for larger water supplies, the ordinary arrangement of the turbine with vertical shaft is preferred in Europe.

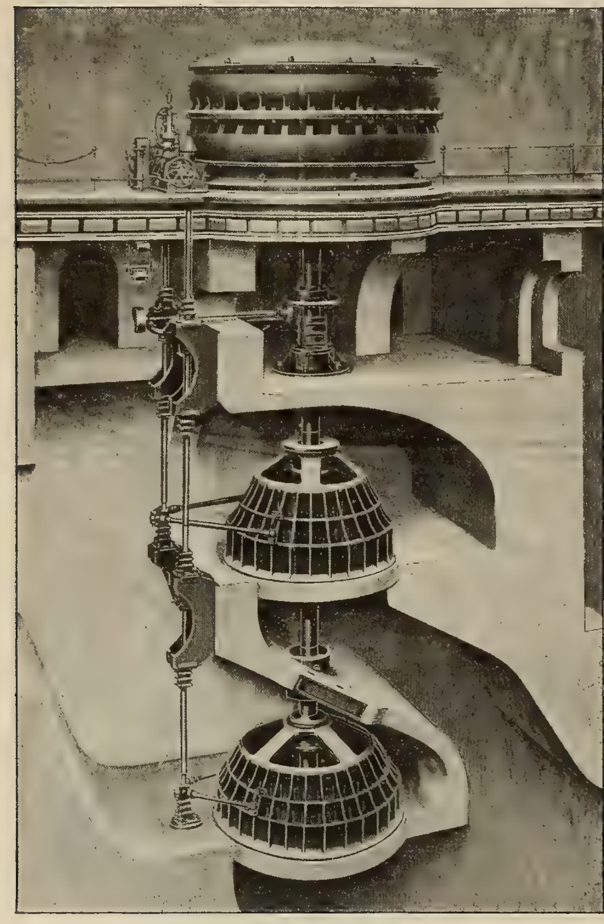
The Fourneyron turbine has, however, been superseded by the Jonval turbine,—a turbine with parallel flow, which by being subdivided into two or more concentric compartments, each of which represents a complete turbine, not only makes it possible to utilise a diminished water supply with practically the same efficiency as at full gate, but also offers the great advantage of obtaining a constant speed under a greatly varying head.

No radial flow turbine combines these advantages of maintaining a high efficiency at part gate and a constant speed under a varying head so much as this parallel flow turbine, and where water

THE ZUFIKON-BREMGARTEN TURBINE HOUSE.

power with such varying conditions is to be economically utilised the parallel flow turbine is preferable. The disadvantage of turbines with parallel flow, that the water pressure is transmitted on to the step bearing, is more than counterbalanced by the advantages named, and is, moreover, a trifle in comparison with the hydraulic losses which occur in many radial flow turbines.

European turbine builders preferably place the step bearing above the tail-water level, fixing it on the top of a column and resting on it the hollow shaft on which the turbine is fixed. The step is thus out of harm from impurities, is always immersed in oil and is easily accessible.



THE 1200 H. P. DOUBLE TURBINES AT CHÈVRES, NEAR GENEVA, BUILT BY MESSRS. ESCHER, WYSS & CO.

These are the essential points in turbines used in the Old and in the New World at present. There can be no doubt that the increased demand of water power for the generation of electricity has, and will have, an influence on the art of turbine building on both sides of the Atlantic.

There are still many large water powers to be found which will become valuable only through the manifold uses to which the electric current can be applied. There is a strong tendency of concentrating such powers in turbines of large units. Since the advent of the Niagara power plant it has been the aim of engineers to build turbines of one thousand and even several thousand horse-power for even lower falls, and dynamos of equal power. It is quite natural that such extraordinary requirements necessitate special and careful attention and that ordinary routine is not sufficient to supply the want.

In dealing with plants of this kind, which will absorb large amounts in capital outlay, a high efficiency, even if attained at extra cost, must be one of the foremost points for the consideration of the turbine builder. The fact that by the ammeter and voltmeter we have a direct gauge for ascertaining the efficiency of a generating plant without troublesome and expensive brake tests at once shows whether or not the turbines of the present day are giving the high efficiency claimed for them.

Many turbine builders who have succeeded in finding buyers for their wares by giving them high-sounding names

THE MOUTH OF THE TUNNEL OF THE ZUFIKON-BREMGARTEN PLANT.

will be obliged to abandon such names for thorough knowledge of a sound theory of hydraulics combined with long practical experience, while conditions over which they have no command will compel them to depart from the notion that any one class or design of turbines will give satisfactory results under all conditions. The cheapness of a turbine does not necessarily make a plant cheap; it may reduce the first cost a trifle, but it may, under any other than the normal conditions, be of little service, or an entire failure, and failures are always costly.

Besides the high efficiency of the turbine, saving of power by a direct drive, without intermediate gearing between the turbine and the machine to be driven, is most desirable. In the case of electric generators, such a direct drive requires great speed of the turbine. Such a speed is easily obtained under a high fall, but not so under a low or moderate fall. With the latter the water is generally distributed over several turbines of smaller diameter, fixed on one common shaft, in order to obtain the high speed required by the dynamo; but there we find again a contrast between American plants and European plants.

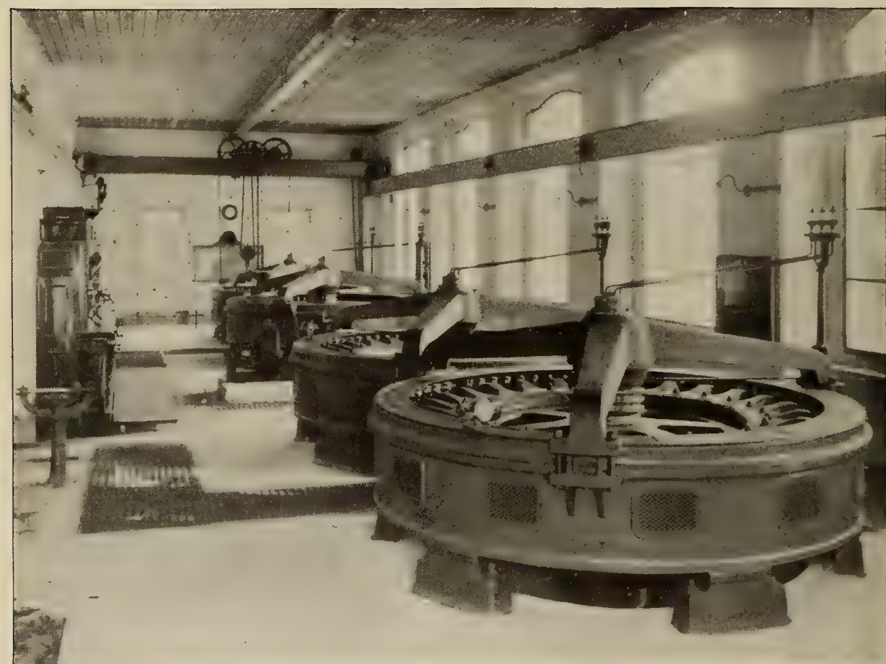
Whereas the arrangement of several turbines on one common horizontal shaft finds favour in America, almost all the more recent power plants erected in Europe have adopted turbines with vertical shafts, the armature spindle of the dynamo which revolves in a horizontal plane being directly coupled to the upper end of the turbine shaft, as adopted for the Niagara power plant. The simplicity of the arrangement and the economy of space leave nothing to be desired.

All the plants illustrated in this paper have been laid out in this fashion, but they differ in the type and design of the turbines adapted for the different conditions and in the manner in which certain difficulties are overcome.

The power plant at La Goule, in the

Bernese Jura, was erected during the year 1894 to supply a number of villages on Swiss and French territory with electric light and power. A constant fall of 82 feet is available, with a water supply from a small lake sufficient to give 4000 horse-power, of which, at present, 1500 H. P. are utilised.

A canal of 1840 feet length, part of which had to be tunneled through the mountain, and a conduit, 7 feet 6 inches in diameter, take the water to the turbines. Three turbines, of 500 H. P. each, running at a speed of 200 revolutions per minute, are now working. The load on the step, caused by the weight of the turbine itself and the revolving parts of the dynamo, is counterbalanced by water pressure.



THE GENERATORS OF THE ZUFIKON-BREMGARTEN PLANT.

Another plant utilising a high fall is that on the wild mountain river Sihl, which provides the industrial villages along the left bank of the lake of Zurich with light and power. For a net fall of 183 feet parallel flow turbines with vertical shafts were again adopted; but, as frequent freshets cause the tailwater to rise, the wheels were placed 10 feet above the lowest tailwater level and were fitted with a draft tube. Each of the five turbines gives 400 horse-power and runs at 360 revolutions per minute.

The celebrated Falls of the Rhine, near Schaffhausen, are, in comparison with the Niagara Falls, like a baby to a giant, but have, nevertheless, been put into the service of industrial enterprise. The manufacture of aluminium and that of carbide of calcium by the electrolytic process are some of the latest industries. To be remunerative they require large amounts of cheap power, such as that available at Schafthausen, where the waters fall over a cliff 66 feet high. A concession to draw water corresponding to 4000 H. P. was granted by the government for this important undertaking.

Outward flow turbines of the Jonval type were adopted, partly on account of the variations of the tailwater level and partly to obtain the speed of 150 revolutions required by the dynamos. For

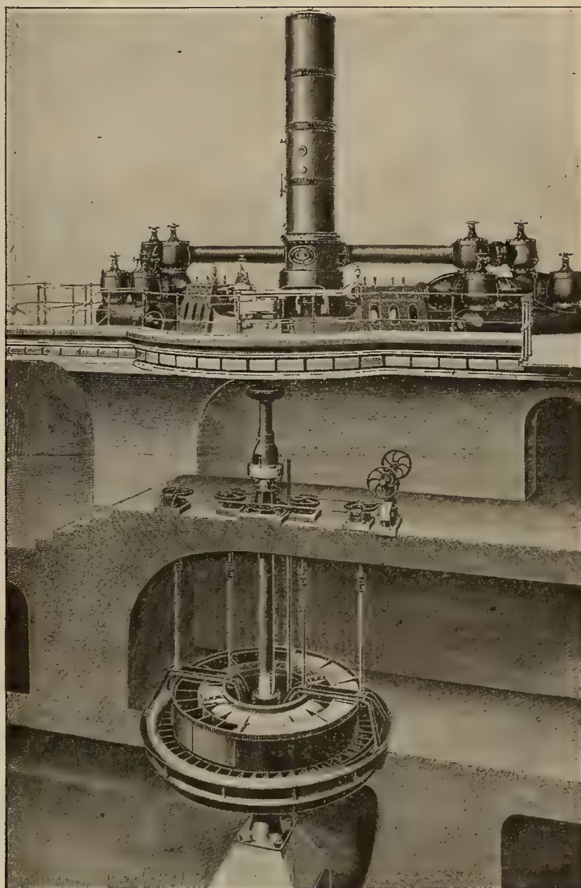
the five turbines of 610 H. P. each, last put in, a novel method was adopted to relieve the step bearing of weight, the turbine being reversed so that the water passes through it upward.

Many remarkable features are found in the 12,000 H. P. plant at Chèvres, near Geneva, described in CASSIER'S MAGAZINE for November, 1896. There the fall varies between 15 feet in summer and 28 feet in winter, while the very large water supply of the summer months is greatly diminished in winter. Ten sets of turbines are contemplated to utilise this power. Of these four sets were erected and successfully started during the year 1895.

Each shaft carries two turbines, cone-shaped, and revolves at 80 revolutions per minute, driving the dynamo direct. While each turbine wheel is divided into three compartments to be regulated without loss of efficiency, the turbine fixed at the bottom of the pit will alone develop the 1200 H. P. under the winter head, while the wheel above works with the lower one under the reduced head of the summer. The hydraulic governing arrangements of these turbines permits their stopping in less than a minute, an achievement most important in electrical generating plants which the makers of this hydraulic plant, Messrs. Escher, Wyss & Co., have successfully originated and applied in many other instances.

With the view of obtaining a speed of 115 revolutions per minute for the generators of 325 H. P. under a 17 foot fall, two turbine wheels were fixed on one common shaft in the interesting plant at Zufikon-Bremgarten, which was erected a few years ago to supply power to the new engineering works which Messrs. Escher, Wyss & Co. have erected at Zurich, at a distance of 12½ miles from the generating station.

To counterbalance the water pressure on the step, the lower turbine wheel was reversed so that the water enters that



ONE OF THE SEVENTEEN 210 H. P. TURBINES AT THE GENEVA WATER WORKS, BUILT BY MESSRS. ESCHER, WYSS & CO., ZURICH, SWITZERLAND.

lower wheel from below, while the upper wheel receives the water in the ordinary way, the space between the two wheels being connected with the tailrace by means of a flume built in concrete. The water is taken to the turbines through a tunnel of concrete, 1150 feet long, which takes the place of iron pipes and is large enough to pass 8825 cubic

feet of water per second at a speed of six feet per second, corresponding to the total of 1300 H. P. which are fully utilised.

Still lower is the fall at Rheinfelden, between Schaffhausen and Basle, where a generating plant capable of ultimately developing 16,800 H. P. is being erected. This will partly be utilised for the distribution of electric light and power within a 20 mile radius and partly for the production of aluminium. Twenty sets of turbines, each to develop 840 H. P., will be erected to utilise the fall, which varies from 8 to 16 feet. The turbines adopted in this case have been fully described and illustrated in Cassier's Magazine, of June, 1897.

Yet another plant may be mentioned, which is unique alike for the large power under the very low fall, at high water, of 5 feet 6 inches, and for the low rate of speed for which the electric generator was built to be directly coupled with the turbine shaft. This is the 1800 H. P. installation at Olten-Aarburg, in Switzerland.

Each turbine, of the Jonval type, is designed to develop 300 H. P. and is divided into three sections to suit the varying head. The speed of the turbine, and, consequently, of the dynamo, is only 23.5 revolutions per minute, probably the lowest speed for which a dynamo was ever built to run. Messrs. Brown, Boveri & Co., of Baden, Switzerland, solved this unique task in the most successful manner.

The above are only a few out of a large number of plants recently erected in Switzerland for the generation of electrical energy, but they show the great variety of conditions with which the Swiss turbine builder has to deal and the difficult problems which are often set to him. They go a long way also to show that neither the hydraulic engineer nor the electrician should attempt to solve such problems alone, but that a co-operation of the two is necessary to secure success.

THE STORY OF THE OIL FIELDS.

By George Ethelbert Walsh.

THE belief is commonly expressed that the opportunities for making great fortunes are becoming more limited in each generation, and that the youth of to-day have less chance to amass great wealth than did our forefathers of half a century ago, while the generations to follow will be more seriously handicapped in the race than we of to-day. The conditions of industrial and commercial life have certainly changed, whether or not these claims are true, and in nothing is the revolution more apparent than in the field of mining for the raw material upon which all our industries are built.

The conditions which made it possible for a few men to accumulate enormous fortunes in the United States are those common to all new countries. The same story was repeated later in Australia, and it is now being unfolded in Africa, while some predict that the future scene for great opportunities will be shifted to South and Central America.

The discovery of raw material in abundance has not always been sufficient to make fortunes, although it has often been the first essential in the process; but the genius which has converted the crude products of the earth into merchantable goods has determined success and produced multi-millionaires. The vast fur wealth of North America a century ago needed only the shrewd business discernment of an Astor to make it the source of a surpassing income; the gold deposits of California required men of great physical and mental powers to mine them from the earth and convert them into stocks and bonds, for while thousands surged across the American continent and engaged in gold mining in 1849, only a small proportion of the wealth remained in the hands of the hard-working miners; the iron mines, the silver, copper and coal mines all had their immense wealth unlocked by the genius of some captain of industry who saw and appreciated the immense possibilities lying dormant in nature.

But of all the romantic stories of creating wealth out of the raw products of the earth, and of building up industries that are almost imperial in their power for good or evil, the petroleum industry is not surpassed, if equalled, in the history of the United States. The great oil fields have been the scene of many shifting romances and tragedies, and not even the El Dorado of the Pacific coast in 1849, created more excitement than men witnessed in Pennsylvania when boring for oil was first started. The discovery of gold in California did not establish a permanent industry on the Pacific coast, but the unlocking of the wells of oil in Pennsylvania was the beginning of a business that has continued to swell in proportions even down to the present. No other industry in America surpasses that of oil production and distribution. The oil fields have naturally been exhausted in places, and prices have come down from what they were in the fifties and sixties; but the gigantic concern which has largely controlled the business for

THE FIRST OIL WELL, DRILLED BY COL. DRAKE IN 1859, NEAR TITUSVILLE, PA. HEIGHT OF DERRICK, 34 FEET. A MODERN DERRICK IS ABOUT 80 FEET HIGH.

the past decade not long ago declared a quarterly dividend of ten per cent., and this meant a distribution among the stockholders of $10,000,000 or more.

Fifty years ago the oil fields were barren stretches of country with a few farmhouses and pioneer cabins scattered over the sun-lit hills and valleys. A scanty living was picked up by the farmers and the operators in the saw-mills, and quiet hamlets clustered around factory towns where iron ore was mined and converted into various useful articles of merchandise. The people were content to live their quiet existence away, earning their bread by the sweat of the brow—all unmindful of the great riches that nature had locked up beneath their feet.

When the gold fever broke out on the Pacific coast many left their homes in Pennsylvania to seek their fortunes in that other State, but they left behind them a wealth that far exceeded the one for which they went to search. If they but knew it, they had the opportunity to amass a fortune that would have made a Crœsus envious. The very rocks upon which they built their houses, and the very fields which they cultivated for grains and fruits, were teeming with the raw material of a new industry that only needed a man of genius to discover.

Oil was so abundant in the earth and rocks that it exuded out of every pore of the surface. It gathered in little pools and ponds wherever there was an indentation in the earth, and oil pits were formed in places, so that the dark-green oil could be scooped up. People "dipped oil" then with buckets. A yard of flannel blanket would soak up enough of the oil, so that by constant

dipping and wringing one could fill a gallon can very easily in the course of an hour or two. Coal oil or kerosene was worth a dollar a gallon, but very few used it for lighting purposes, and the old tallow dips remained popular for some years later. Nevertheless, the oil-dippers made money. Some even dug for the oil, increasing the size of the pits so that the oil would flow into them in such a way that they could scoop it up without the use of the blankets.

There is an account of an oil well dug in Wayne County, Kentucky, as early as 1819, and another in Cumberland County, in 1827. This latter has been flowing ever since, and to-day it is one of the largest in existence. It has been improved and enlarged upon since its first digging, and modern machinery has increased its flow and capacity; but its chief claim to notoriety is its very early history. It was dug before oil-drilling revolutionised the industry in Pennsylvania and Ohio. It had been flowing for years before the oil-dippers were crowded out of existence by superior methods of oil mining.

The value of the oil that was gradually forcing its way out of the earth was not appreciated by the early settlers in those regions. It was not supposed to possess the same valuable properties that were found in coal oil, and the natural oil wells contained little of significance to the population. It seems strange that such was the case, for the value of petroleum had been recognised since the days of the early Grecian and Roman writers, who describe its use to feed the sacred fires in the shrines of their temples. Pliny mentions the use of it in lamps. Genoa was lighted with the petroleum taken from the wells of Amiano long before America was discovered.

But one day the attention of a visitor to the oil regions was attracted by the appearance of oil oozing out of the earth and rocks, and he collected a bottle of it to take back with him. This was Professor Crosby, of Dartmouth College, who was visiting friends at Titusville, in northwestern Pennsylvania, and his analysis of the oil satisfied him that there was money in the product which was going to waste. A son of the professor was sent to the oil fields to make further investigations, and on the strength of his father's representations he succeeded in interesting others in the first real enterprise of collecting the petroleum for commercial purposes on a large scale. A joint stock company was formed, deeds were written out, stock certificates issued, and the first real estate transfer of oil-producing property was made on Oil creek.

While this was the first important step in mining for oil, it was many years before the wells began to produce such fabulous quantities that even at this late date it seems difficult to believe. The oil-producing property purchased by the new company embraced seventy-nine acres of land, including the island at the junction of Pine and Oil creeks, on which the famous oil spring was found. The deed was transferred to

COL. EDWIN L. DRAKE.

the new company for the consideration of $5000 (£1000). The new "Pennsylvania Rock Oil Company" issued stock certificates for $250,000 (£50,000), most of which were sold in New York, although it was extremely difficult to find purchasers.

A NEST OF DERRICKS IN THE CENTRE OF THE OIL TOWN CYGNET, OHIO.

Considerable uncertainty was connected with the new venture, and capitalists were conservative about investing in the enterprise. Moreover, the members of the experimental company had no definite and well-laid plans to secure the oil which was supposed to exist in considerable abundance somewhere beneath the surface. Nevertheless, there was growing up a general feeling throughout the oil regions that fortunes were to be made in oil; still nobody seemed to have the shrewdness to guess how. The professor who had discovered the value of the oil was not an engineer, and he could not be expected to tell the men how to obtain the oil in paying quantities. The fruit was ripe for harvesting; but the man was not forthcoming who could devise a way and means to pluck it.

Machinists and engineers were sent to the oil fields to investigate, but all they could do was to establish a very primitive sort of plant. The oil pits were increased in numbers by excavations, and then shallow trenches were dug to empty into these pits. The water and oil flowed into these catch basins, and then pumps were used to draw the liquid out and pour it into shallow troughs. The oil floated on the surface of the water, and as the two passed from one shallow trough to another a man skimmed the oil off. In this way it was gathered for commercial uses until everybody was tired of the process, and ready to throw up the business.

The "Seneca Oil Company" was formed in New Haven soon after the organisation of the "Pennsylvania Rock Oil Company," and the lands of the latter were leased, and an agreement entered into to pay a royalty for all the oil produced.

Meanwhile, accident, which, after all, is more often the mother of invention than necessity, disclosed to one inquiring, wide-awake mind the way to obtain the oil from its subterranean prison house. Mr. George H. Bissel, a New York lawyer, who had been instrumental in forming the first oil company, and a friend of Professor Crosby, happened to see in a New York drug store some petroleum advertised as a medicine. According to the circular, the wonderful properties of this petroleum were due to the fact that it had been obtained from salt beds four hundred feet below the earth's surface. The salt company had been boring for salt water when the oil was discovered.

The idea of boring for oil instantly suggested itself to Mr. Bissell. He went home and made studies of the latest methods of artesian well boring. When his idea was thoroughly developed, he explained it to the directors of the New Haven company, and instead of being skeptical at the idea they accepted it cheerfully. This may have been partly due to the fact that the company was on the verge of dissolution, so unsatisfactory had surface development become. Other capitalists were interested in the scheme, and preparations were made immediately to try the new experiment.

Colonel Edwin L. Drake made the first artesian borings early in the following year at the mouth of the oil spring; but his tools and machinery were of the most primitive kind, and his unskilled labourers found difficulty in keeping the well free from dirt and gravel. To expedite matters, and to make sure of his work, Colonel Drake employed two skilled borers who had been employed at the salt works at Tarentum, near Pittsburg, and on May 20, 1859, he began boring in earnest. The method of boring then for salt was to dig a well down to the bed rock, and erect timber derricks to start the drills in operation. When the men attempted to dig the well at the oil spring the water constantly caved in the earth, and caused considerable trouble and delay.

Colonel Drake was a man of an inventive turn of mind, and he succeeded in boring for oil without digging a well, and gave birth to an invention that has been worth millions to the oil industry since. A large iron pipe was driven with considerable force down into the soft clay and quicksand until it reached the bed of rock. Then through this the drill was enabled to begin its work on

PUMPING OIL FROM A WELL.

the rock at once. The pipe was forced thirty-six feet through the earth before it struck rock bottom, and the drill worked its way down to a total depth from the surface of seventy feet. Oil was struck at all points in the rock, but at this depth there was a flow that brought the fluid close to the surface when the drill was removed. An old tin water spout was dipped down into the hole, and when it was brought up full of oil the wildest excitement passed through the region.

An oil pump was inserted into the well, and oil was pumped up for the first time from the capacious bowels of the earth. The flow of the oil into the well proved so abundant that from twenty to thirty barrels were pumped up every day. The news of the successful experiment traveled rapidly, and the Drake oil well was surrounded by hundreds of curious and interested people. Everybody seemed to realise the importance of the new discovery. Hundreds of people saw visions of wealth before them. Every owner of an acre lot near the successful oil well doubled, tripled and quadrupled his former price for it. There were plenty to lease the land from the owners, offering to pay them good prices for the products, but few cared to run the risk of giving away a fortune for a mere song. Every one believed that unknown possibilities dwelt beneath the rocks for him, and the oil land was leased to the speculators on the share or royalty system.

The boom of the oil land increased, and the capacity of the first well seemed

unlimited. The supply of oil continued to flow steadily through the opening. The question of storing the great quantities that were pumped up became serious. All the barrels, tubs and hogsheads in the vicinity were pressed into service. Then they sent to Erie, forty miles away, for more barrels, and finally the nearest cooper, who had made a living making barrels and butter tubs for the farmers, was engaged permanently to manufacture barrels for the oil company. He could not work fast enough to keep up with the continuous flow of the oil, and assistants had to be employed by him to increase the output of his small factory.

Meanwhile, others were boring for oil, and dozens of pumps were soon in operation sucking the oil from the rocks below. The large and unexpected supply of crude oil naturally had an effect upon the price, and as no arrangements had been perfected beforehand to market the product, it dropped as low at ten cents (5d.) a barrel. A number of shrewd speculators bought up considerable quantities of the oil at this price, stored it, and finally sold it at an enormous profit. But this price was only temporary, caused by the sudden expansion in the supply, and Colonel Drake soon made arrangements to dispose of one-third of his product to a Pittsburgh dealer in a refined illuminating oil made from coal. The crude petroleum was sent to Pittsburgh on lumber scows and rafts, and after being refined it was sealed up in tin cans and put on the market as "Seneca Oil."

Illuminating oil was just coming into fashion then, but owing to its high cost only the wealthy could use it generally. The new illuminating oil, made from the natural product of the oil fields, was sold at $1.25 (5s.) per gallon. But a new difficulty presented itself. The old tin lamps with a round wick were inadequate for burning the new illuminating oil, and there was danger of explosions and general conflagrations. A new kind of lamp had to be made to suit the new product. Once more the ingenious and indefatigable Colonel Drake set himself to work to remove the new obstacle in the way of his success. He either designed, or helped somebody else to design through his suggestions, a glass lamp with glass chimney that perfectly answered the needs of the trade. The lamps retailed at $1 (4s.) and $1.50 (6s.) each, and the

A VIEW OF AN OIL TANK FARM.

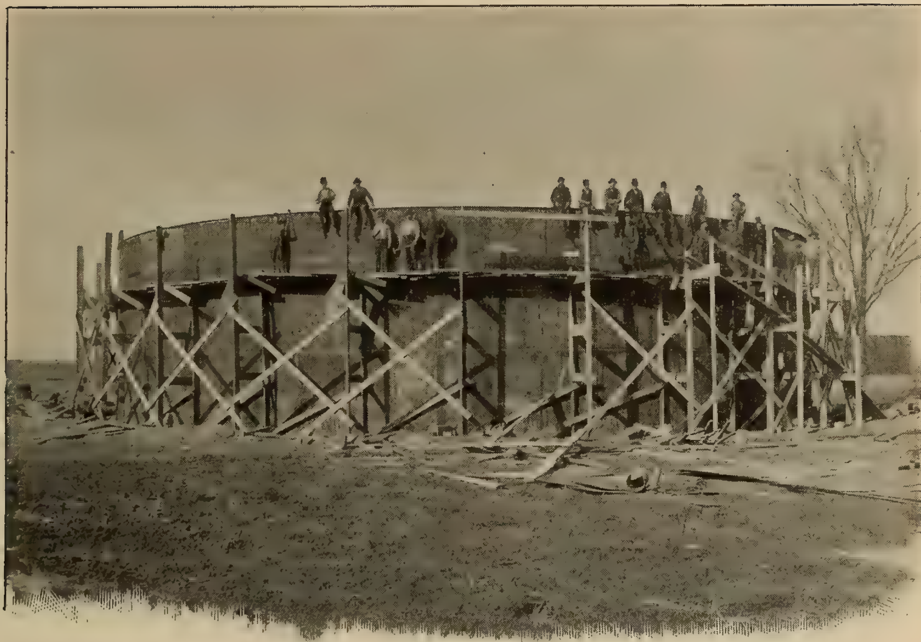
new chimneys at twenty-five cents (1s.). They became popular at once, and while the owners of the oil wells made money in selling the product of their plant, the manufacturers of glass lamps and chimneys made fortunes in even less time.

In July, 1860, the total output of the wells on Oil Creek, in Pennsylvania, amounted to 200 barrels a day; but in one year from that the regular supply was estimated at from 6000 to 7000 barrels per day. And the excitement was not at its height then! People were flocking to the oil fields in ever-increasing numbers. Farmers, who had thought themselves poor with a few hundred acres of barren soil in their possession, suddenly found themselves on the royal highway to fortune. A few sold out their possessions at fabulous prices, but the majority were more anxious to bore for the oil themselves. Considerable capital flowed into the region, and companies were organised to drill for the oil; but many of the local residents who could not afford the expense of a large oil-drilling plant adopted a method of surface boring that answered very well for a time.

The "spring-pole method" of boring for oil was unique and primitive, but it was very successful to a depth of from thirty to fifty feet. Beyond that the rock drill had to be employed to let loose the oil from its imprisonment. A green sapling, ten inches in diameter at the butt-end, and from thirty to forty feet in length, was firmly fixed in the ground. The small end was then bent over until the middle reached an upright post ten or fifteen feet from its base. The spring-pole was attached to this post, which acted as a fulcrum. Then to the end of the spring-pole the boring machinery was attached. Thus equipped, two or three men could operate the machinery. The stroke was given by several men throwing their weight upon the end of the spring-pole, and, by releasing their hold, the upward motion was given by the spring of the pole. Thus back and forth, up and down, the pole went while the drill slowly made its way down through the soft earth and clay.

PUMPING OIL FROM A WELL INTO A SMALL TANK TO BE TRANSFERRED TO A LARGER TANK.

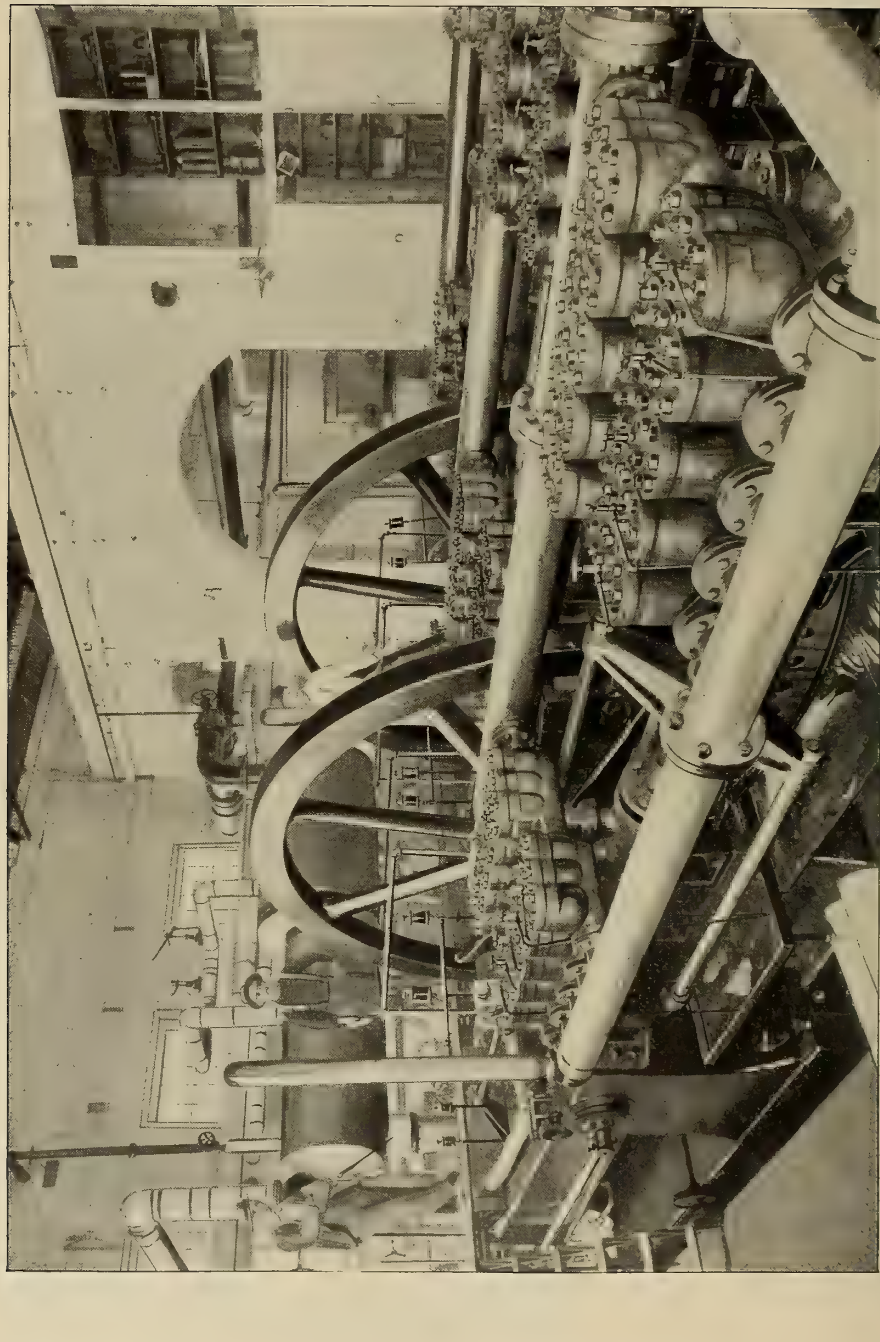
The organised and capitalised companies left the surface boring to the resident spring-pole boring companies,



A THIRTY-FIVE THOUSAND BARREL TANK IN COURSE OF CONSTRUCTION.

and devoted their attention to deep rock drilling. In June, 1861, the first really deep well was drilled, and to the astonishment of all the oil spouted up of its own accord. This discovery marked another era in the industry. It was realised then for the first time that great underground reservoirs of oil were imprisoned beneath the lower rocks, and that it was subjected to such a pressure that it needed only a slight opening to force it up to the surface. To reach these subterranean oil reservoirs it was necessary to bore down several hundred or a thousand feet. The spouting geysers of oil, shooting far up into the air, attracted more people to the scene of operations than the discovery of the first oil well. It was a sight rare to see, especially when for some reason or other the oil caught fire, and blazed away for hours and even days. This discovery was sufficient to attract men of genius and of capital to the oil fields. At first the limits of productive territory were thought to be comparatively small,—that is, within a rectangle of 2000 square miles in northwestern Pennsylvania. But as developments of

OIL TANKS STRUCK BY LIGHTNING.



INTERIOR OF THE PUMPING STATION NEAR CYGNET, OHIO.

the fields continued, it was found that the oil belt extended into Southern Pennsylvania as well and into West Virginia, and westward into Ohio and Indiana. The production increased so rapidly that the price of illuminating oil quickly dropped to a point where every one could afford to use it for lighting purposes. In 1874 the yield amounted to 6,500,000 barrels. But even this was a mere bagatelle to what was coming. In 1890 there were exported 664,491,498 gallons, and an enormous quantity was used at home. Every day in the week from six to eight vessels leave New York City loaded with petroleum.

Huge fortunes naturally were realised by some of the men engaged in the enterprise. No such opportunities for money-making had been presented before. There were five men in particular, who, living near the oil region, saw great monetary possibilities in the awakening industry. They were comparatively poor, but they were shrewd and progressive enough to invest their small capital and their large brains in the petroleum business. They were early in the field, and worked up with the industry. In time they formed the Standard Oil Company, which developed into the most gigantic concern that ever sought to control an industry in any country of the world, and to-day the organisers of that company represent in the aggregate a fortune of about $600,000,000 (£120,000,000).

When gas and electricity were introduced for illuminating purposes, it was predicted that petroleum and kerosene oil would be gradually pushed out of use, and that the vast interests in the oil plants would depreciate and ultimately ruin the owners. By the time that gas and electricity were adopted in towns and cities, the oil companies had spent fortunes in their huge plants, and it would have meant a ruinous waste of capital had they been forced to shut down. But as time passes, the false prophets cease to proclaim what they now realise is untrue. The demand for petroleum has increased, and continues to increase. It is used in a hundred different ways now where it was used in only one way thirty years ago.

THE OIL PUMPING STATION NEAR CYGNET, OHIO. THE LARGEST IN THE WORLD.

When the crude oil flows from the wells it varies in colour from a bright

lemon to a greenish black, and it gives off methane, ethane, and propane in gaseous form. By distillation various chemical products are obtained from the pure petroleum. First the temperature of the oil is raised until the most volatile constituents pass off in vapour form. This vapour passes through coils of iron pipe surrounded by cold water, and as it condenses it produces naphtha and benzine and kindred products.

The second process is to extract the kerosene or illuminating oil from the petroleum. This comes next from the still, being lighter than the other constituents of the petroleum, and the lubricating and heavy oils are left behind. The crude naphtha is re-distilled, and from it gasolene, rhigolene and several other "enes" and "ines" are obtained. Several grades of heavy lubricating oils and paraffine wax are made from the residuum left in the still. Nearly all of these various substances are divided and subdivided into other parts, forming new and useful products for the market.

But, after all, the main use of the oil is for illumination, and the greater percentage of the supply is consumed in this way. It is not at all probable that it will be superseded in the next century or two by anything superior, and accepting this view of the situation capitalists do not hesitate to put money in the gigantic plants erected for the purpose of handling the oil. Enormous outlays have been made to get the oil to market so that it could be sold at a low cost, and nothing but time, money, and brains could ever accomplish this.

When the oil fields were first operated on a large scale it was the custom to fill specially made barrels with the crude petroleum, and then cart them over the rough roads to the nearest stream of water. Usually this meant to Oil Creek, and from there loaded barges were floated down to the Allegheny river and thence to Pittsburgh. One barge would carry about two thousand barrels, and it took a great many teams to haul one load to the barge wharf. As the business increased, railroad lines were built through the oil fields, and, in time, huge tank cars were run direct from the wells to the cities. The tanks were built of iron boiler plate, twenty-four feet long and sixty-six inches in diameter, with a capacity of several thousand gallons. They were fitted on flat cars which carried them direct to their destination. and when the oil was pumped out, returned with them to be again filled. This facilitated transportation wonderfully, and brought down the cost of illuminating oil.

But for twenty years now this has been an antiquated system. In 1865 the first pipe line for oil was constructed, and from that time down to the present the system has been rapidly extended. In 1876 there were nearly 1500 miles of pipes, and to-day there is a perfect net-work of pipes extending all over the oil fields and to the chief cities. The longest pipe line runs from Olean, N. Y., to Bayonne, N. J., covering, in all, a distance of 300 miles. One trunk line from Colgrove, Pa., to Philadelphia is 280 miles long. These pipes conduct the oil direct from the fields to the principal markets and cities, saving the cost of transportation by rail or boat. Thus the oil that is to be exported is pumped through the pipes to Bayonne, N. J., or to one of the Long Island refineries, and then put up in cans or barrels for the ships that load in New York City.

Powerful pumping machinery is employed to force the crude oil through the pipes to such enormous distances. At about every twenty or thirty miles along the route a pumping station is erected. At this there are two enormous iron tanks, thirty feet high and ninety feet in diameter. The oil is pumped from one of these to the other, and so it goes on its journey across the country. Between Olean and New York there are eleven such pumping stations.

Naturally, the piping used for this purpose must be of extraordinary resisting power, for the pressure is great. Before it is laid, the piping is tested to a pressure of 1500 pounds to the square inch. A stream of oil, forced through a leak in the piping, has been thrown a hundred feet into the air.

Not only has the system of transportion been improved in recent years, but progress has been made as well in the methods of boring for the oil. The average depth of the drilled wells in Pennsylvania is between 500 and 1000 feet, but it is not uncommon for the drill to go down to two and three thousand feet. The cost of drilling and opening an oil well thus varies all the way from $2000 to $8000 (£400 to £1600).

The machinery used is all of the most recent invention. A wrought-iron drive pipe is first forced down to the bed rock through the strata of clay and gravel. Then the drill is inserted until the oil-bearing stratum is reached. The drill first passes through rocks containing more or less water, and an ingenious device is attached to the drill to prevent the water from going into the oil sand below. Next the drill strikes stratified rock that seldom bears water, but which contains oil sands.

Formerly when the oil could not be released from its prison by the drill, a torpedo, filled with nitro-glycerine, was lowered into the well. Then the "go-devil," a cast iron weight, was dropped down upon it, causing it to explode. To-day a dynamite cartridge is used, which is exploded at the will of the operator at any depth below the surface. The explosion under the ground causes no special shock to the earth,—simply a slight vibration; but almost instantly a huge stream of oil spouts up into the air and falls like a beautiful geyser. When the wells do not flow of their own accord, pumps are inserted, and the "grasshopper" will work several of these pumps at the same time. The "grasshopper" is a kind of walking-beam arrangement which works up and down, giving power to a number of pumps.

There is some talk now of applying electricity to oil mining, and an invention has been patented which is intended to melt the refuse matter that clogs the pores of the stone. Many of the old wells are exhausted to-day, but it is supposed that they would run again if the pores of the stones were opened. On the other hand some believe that the oil wells are nearly exhausted, and that the present supply will not continue many more years.

Whatever may be the future of the industry, it is certain that invention and

SHOOTING AN OIL WELL.

persistency of man have unlocked from the earth a product that has been of great economical value to humanity. It would be difficult to point to any other raw product of earth that has accomplished more in adding to the comforts and pleasures of civilised nations

IS THE INVENTIVE FACULTY A MYTH?

By W. H. Smyth.

THAT a man is born an inventor is not questioned, but that he is born an inventor in any way more specialised than another is born a farmer, or, in fact, a specialised exponent of any other art, trade or calling, is emphatically denied. The existence of any such organ, sense or faculty as an "inventive faculty" of "creative imagination" is also denied with equal emphasis.

Normal human beings are born possessed of like physical faculties. Their mental endowments are alike. In the same manner that the strength, acuteness and vigour of the physical faculties vary in individuals, so, and only so, do the mental faculties vary, though possibly in greater degree. This is wholly at variance with the accepted idea that invention is the product of an inventive faculty which is isolated, sporadic and fortuitous in distribution, spontaneously creative in function, irreducible to law, order or system, and irresponsive to education or cultivation,—a gift, a philosopher's stone, an Aladdin's lamp.

That practical men should continue to accept such a mystical and entirely poetical explanation of an ordinary form of mental activity, is one of those curious survivals of a less critical age which surprise us now and then in every department of knowledge. It is as much out of keeping with the spirit of this age and the logic of observed facts, as an astrological chart would be in an astronomical observatory. The obscurity which, from the nature of the case, surrounds all mental operations, probably accounts to some extent for the persistence of this erroneous view.

The suggestion that invention is the result of reason which acts to select and combine things observed through concepts of them in accordance with their known qualities, not only appeals to sober judgment, but is in accord with acknowledged facts and explains much that is inexplicable on any other hypothesis. One such obscurity is the fact, that preliminary to invention there must be a want, *i.e.*, a pre-existing and active condition of dissatisfaction—in other words, a lack of adjustment to environment. An invention without a pre-existing want is inconceivable, for it is that which supplies the impulse. This alone is sufficient to discredit the self-creative or spontaneous conception idea of invention.

FIG. I.

If the products of the inventive faculty differ in no way from those which are the result of faculties possessed in common by all, and the normal mental faculties are capable of producing absolutely the same results as are ascribed to the supposititious one, it would seem that, as a factor in ordinary affairs, this hypothetical faculty may be ignored.

The improbability of its actual existence also becomes so great that its non-existence may be accepted as a fact.

To illustrate this line of thought let us try to imagine how some primitive device came about,—a time-measuring contrivance, for instance.

It had, no doubt, been observed many times before the want of a time measure became urgent, that a leaky vessel became empty while a definite amount of work was being accomplished,—say, a hand's breadth of fabric woven. The perception of the relation which the observed fact sustained to measuring time generally was then all that was required to constitute the leaky vessel a primitive hour glass, to satisfy the want and produce an invention.

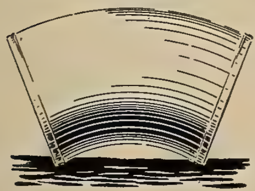


FIG. 2.

This illustrates invention of a character which is hardly distinguishable from observation pure and simple. Strange to say, the most complex and involved invention is only an aggregation of just such simple wants which have been individually supplied. This, the following synthesis will show. That it is not a hypothetical case, arranged to give point to this argument, but the story of an actual series of experimental machines, built and operated under commercial conditions at the cost of a goodly sum of money, must, I think, add to, rather than detract from, its interest and significance. It may be added that examples, like the one following, are by no means rare; they are, on the contrary, customary experience. Every inventor who reads this will, I know, think with a sigh of his own "graveyard."

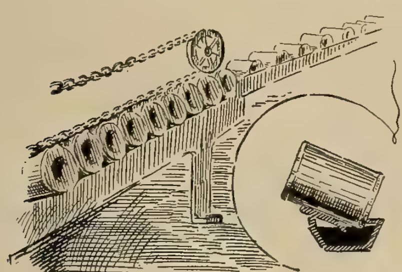


FIG. 3.

The problem to be solved, or, as I have previously expressed it, the want to be satisfied, relates to means adapted to solder both ends simultaneously on fruit cans in the time previously required for one end. The mental material available for the solution of the problem consisted of a somewhat extensive acquaintance with mechanical devices generally, and a limited one with the state of the art relating to soldering devices.

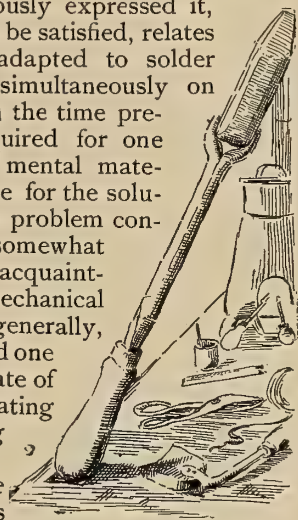


FIG. 4.

As the mechanisms for handling the cans are not necessary to the illustration, it may be assumed that they were of a character to suitably feed and discharge cans in the varying conditions under which the solder was applied. They will, therefore, be no more particularly referred to.

The state of the art before spoken of embraced solder in bulk, bars, rods and wire; hand tools, such as soldering irons of various forms, and furnaces of different kinds for heating them, adapted to use solid, fluid and gaseous fuel. It also included fluid solder in open troughs, *i.e.*, solder baths through which, for the purpose of applying solder, cans were caused to roll in an inclined position, dipping the cover joint beneath the solder surface.

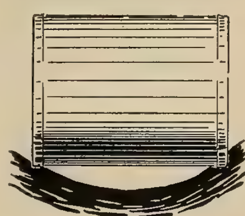


FIG. 5.

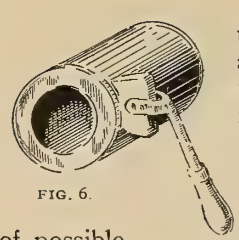


FIG. 6.

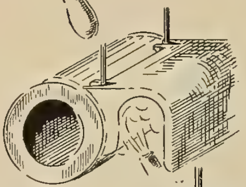


FIG. 7.

The first procedure was, of course, a survey of the material. This immediately disclosed two distinct lines of possible devices, one, based upon the employment of solid solder, and the other upon the use of the fluid solder bath. Rapidity and simplicity, two extremely desirable qualities, are presented by the bath; consequently its possibilities received thorough consideration, resulting in two equally unpromising alternatives. The first of these involves bending the can so that its opposite ends may dip simulaneously in the solder, as in Fig. 2, and the second, bending the fluid up to meet the ends of the can, as in Fig. 5.

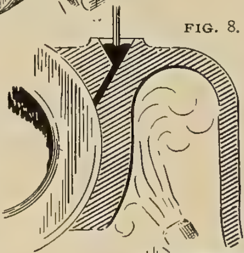


FIG. 8.

These alternatives proved so extremely unpromising that consideration turned to the solid solder devices. In this direction the problem, in its essence, simply means a duplication of hand tools operated and fed automatically. So the device assumed the form shown in Fig. 6 with gratifying results, excepting only that the solder wire would, at times, leave the groove prepared for it.

Perforating, instead of grooving, the iron, and supplying a funnel-shaped cup to direct the wire, remedied the defect. This improvement not only avoided a difficulty, but pointed in an unmistakable manner to a way of dispensing with the complicated and delicate mechanism necessary to feed the wire solder. In practice, the funnel-shaped cup became a miniature reservoir of molten solder (Fig. 8). So, for the reason suggested, the little reservoir was enlarged and a simple valve added to regulate the flow (Fig. 9). This slight modification, it will be seen, unintentionally carried the device into the fluid category, previously abandoned as hopeless.

It was now observed that owing to the much greater heat of fluid solder, the contact between iron and can was entirely too large. The bearing surface was, therefore, gradually cut down to almost mere contact (Fig. 10) with increasing improvement in result; but at this stage a trouble developed which had not been previously experienced to any serious extent. The friction between iron and can became a factor. The irons wore out much too rapidly.

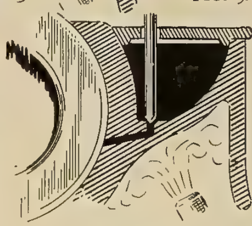


FIG. 9.

Here, then, was a conflict of requirements. Small contact for soldering,—large surface for wear,—in one and the same contact. How could these diametrically opposing conditions be harmonised? Rolling contact is immediately suggested, and was adopted in the manner shown in Fig. 11. This served the purpose excellently, so far as concerned wear; but, owing to the large exposure of the soldering wheel, too much heat was lost. So what was gained in wear was more than offset by loss of soldering capability.

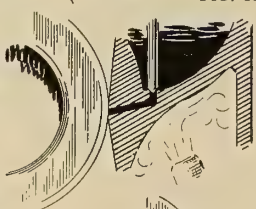


FIG. 10.

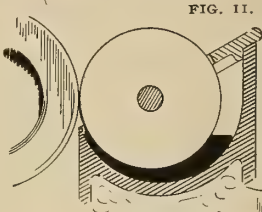


FIG. 11.

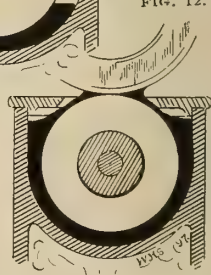


FIG. 12.

However, the remedy was obvious,—reduce the exposure (Fig. 12). Nothing could be, apparently, more simple and satisfactory, for the device

is now in form to solder simultaneously, not only both ends of one can, but both ends of a practically unlimited number. A further advantage is incidentally achieved in that the cans, by rotating the solder discs, control their own solder feed. It is interesting to notice at this point also that the seemingly paradoxical feat of causing the solder surface to bend upward to meet the ends of a horizontal can is accomplished (Figs. 13 and 14).

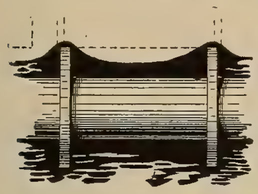


FIG. 13.

Up to this stage the cans are soldered in batches, the units of which must be fed and discharged simultaneously. The question is naturally suggested, could the same results be obtained upon cans fed in a continuous stream? This accomplished, the wished-for goal is reached, though by a somewhat unexpected way.

To those who have carefully followed the solution thus far, the necessary change will offer little difficulty. It is, in fact, almost obtrusively apparent, needing but one stroke of a pen to the sketch represented in Fig. 15. Discs are dispensed with and the conflicting requirements which suggested them are even more perfectly harmonised in the later construction.

Assuming, then, the last step taken, a device appears which applies solder to both ends, simultaneously, of each unit of a continuous stream of cans, rolling in single file upon horizontal axes above a horizontal surface of solder at the same or greater speed than cans are soldered at one end by rolling in the same bath in an inclined position.

It is readily seen that this evolution does not involve creation or even spontaneous conception of ideas and that it is simply the application of known facts to satisfy previously unsatisfied wants. Each step is but slightly removed from mere observation. But suppose all the intermediate steps to be hidden,—what imaginable nexus could be supposed to exist between the hand tool of the first stage and the device of the last? Under such imperfect presentation of facts it is not altogether surprising that the last device should be regarded by those not versed in such matters as the result of spontaneous creation. That any rational mind should arrive at the same conclusion in the knowledge of the intermediate steps would, however, be surprising indeed. It is a curious and suggestive fact that the Patent Office and courts would not hesitate an instant to decide that any one of the steps does not involve "invention," but hide one or more of the steps and the same tribunals will discover invention of a high order.

The contention that invention is instantaneous and that inventions are the result of a flash of thought, or intuition, may be disposed of by another illustration,—the firing of a rifle. The finger presses the trigger which moves several degrees in the arc of a circle, thus liberating the compressed spring. This, in turn, forces forward the striking bar or hammer, the impact of which causes a breaking up of the unstable chemical compound of the detonator and the ignition of the powder charge in the cartridge. Combustion of charge has the effect of evolving gradually large volumes of gas under increasing pressure until the charge is consumed and the friction of the bullet in the cartridge is overcome. The bullet then moves forward at accelerating speed, meanwhile revolving upon its axis, owing to the rifling of the barrel. The commencement of its journey is announced by the

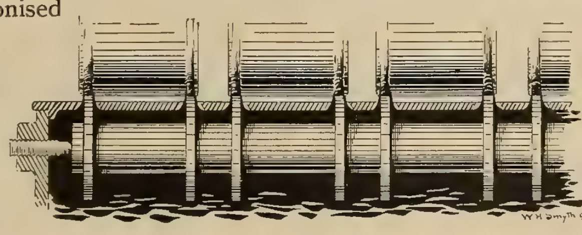


FIG. 14.

report,—the result of the impact of the liberated gases upon the atmosphere,—a small fraction of a second after the finger pressed the trigger.

This by no means extreme example shows how much can be crowded into an instant of time. It does not therefore appear that the supposed instantaneousness gives much support to the creation idea.

Ascribing to imagination qualities which are foreign to it, is another source of difficulty and misconception. Imagination is not only credited with reason, but also with the capability of spontaneous origination,—creation in fact. Imagination is the image-making faculty. To imagine does not mean to create, but to reproduce, to represent. That which is non-existent cannot be imagined. There cannot be an image without an objective reality. Imagination is the mirror of observation, not an organ of spontaneous conception. In a word, imagination does not originate or create; it simply reproduces; creative imagination is a contradiction of terms—a paradox. At the boundary of the known, imagination stops.

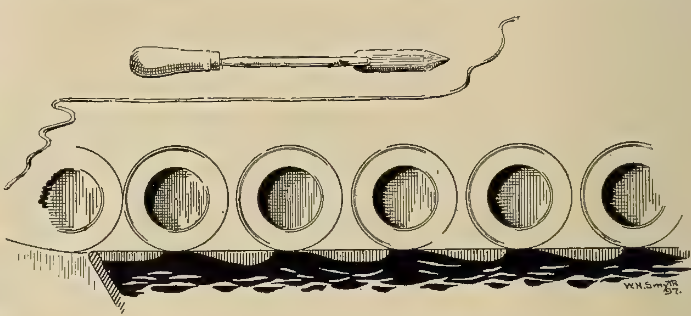


FIG. 15.

If, when a want had been perceived, it were necessary to begin an investigation throughout nature for the facts which would fit the requirement, invention of even the simplest character would be a task of Herculean character. But memory is stored with multitudes of facts, the result of observation, conveniently arranged for reference. These imagination reproduces, and reason makes selection.

Thus it will be seen that faculty in inventing depends upon,—

First, the character and amount of material with which memory is stored.

Second, the accuracy with which the mental pictures, presented by imagination, correspond to the objects reproduced.

Third, the logical skill in dealing with the material and relations involved.

Briefly, correct observation, clear visualisation, retentive memory, logical reasoning. In fact, invention is none other than the application of an ordinary mental process in a particular direction. It is the conscious effort of reasoning beings, deliberately adjusting themselves to their environment.

It is now pertinent to ask if preparation for conscious and deliberate self adjustment to environment is not the proper aim and end of education? That it is so, hardly admits a doubt. The question, therefore, naturally follows, what practical course will effect the desired result? This I will endeavour to answer briefly, applying the method already outlined. The human race has arrived at its present stage of physical and mental development and adjustment to environment through the action of natural law. It would seem, therefore, that the race history should give valuable clews to the proper training of the individual. This expectation is supported by the facts of embryology and the known continuity of nature's processes. Prenatal development parallels the prehuman progress of the species, obviously suggesting that in like manner the race history and development would be paralleled in the period of adolescence, and this is borne out by a multitude of facts.

The first necessity with primitive man, as with other animals, was bodily sustenance under the varying conditions of

his environment. His first study, therefore, was observation of his surroundings; the appearance, nature and effect of things. On correct appreciation of these qualities success depended, and only those who avoided serious mistakes survived.

The next step, still in the line of scientific observation, was to learn how the natural objects whose qualities had been ascertained could be utilised, and later, selection and simple combinations of natural objects with relation to their ascertained qualities to accomplish specific ends. Heavy objects, it was found, increased the effectiveness of blows, pointed ones pierced, sharp ones cut. From the observation that naturally-split flints had sharp edges, splitting them for this purpose intentionally, followed inevitably; and from cut, bruised and broken hands, the result of awkwardness, arose skill and dexterity just as inevitably. Increased skill resulted in greater efficiency of product. More perfect tools necessitated greater skill in their use. Improvement in each thus ever reacted on the other. Skill is only another name for intelligence, for increased skill means closer observation and also more accurate co-ordination of mental impulse and physical expression.

As a necessary factor in this increasing skill and dexterity there must have been present, even at this early stage of human intelligence, quite well-developed, the capability or faculty of visual memory, the ability to recall and mentally see the image of past visual impressions.

That such faculty did exist is practically proven by the fact that almost the earliest traces which have been found of our half human ancestors are correct and artistic representations of animals scratched on bone. The probability verges on certainty that the paleolithic artist sketched from memory, that he drew from the visualised image called up before his mind. The earliest writing was picture writing, which, in the nature of the case, must have been done from visual memory.

Thus far the education of the race consisted wholly in the acquirement of knowledge by direct personal observation of nature, and the attainment of personal skill. With the advance indicated, the capability for drawing inferences of simple and obvious kind must have increased and strengthened in the direction of conscious and connected reasoning.

The race finally attained such skill and proficiency as a bread-winner that it could supply its physical needs and have spare time to cultivate the less important accomplishments. Then came the desire, and later the means, for storing some of the acquired knowledge and experience, and also those arts which add dignity and beauty and pleasure to life.

There is a suggestive fact clearly observable in all this infinitely slow growth of the mental faculties, namely, the hand was the implement which verified visual perception and gave tangible expression to the workings of the mind. The connection between the hand and the mind has been so inseparably intimate that it is questionable to which the final result is due in greater proportion. Be this as it may, there is no question that the human race owes its pre-eminence to that incomparable piece of mechanism,—the hand.

The drift of all the foregoing is obvious; still a brief summary will not be amiss. We have found that what is loosely termed invention is a process of logical thinking on natural objects and phenomena, presented in suitable form by visual memory, having as object the satisfying of existing wants, whereby better adjustment to environment is made, consciously and deliberately; that the object of education is to cultivate the faculties in such a manner that the capacity of adjustment to the present environment shall be more fully within control of each individual; that the human race has, during its upward progress, acquired, from time to time, mental faculties necessary to its better adjustment to environment, and these faculties are the same that are used deliberately in that form of intentional adjustment loosely termed invention and which it is the specific object of educa-

tion to foster and cultivate; that through the action of the natural law of necessity the race has acquired those faculties in a certain definite order of succession; and finally that education, to be successful, must adopt nature's order in the cultivation of those faculties.

A rational system of education, based upon the foregoing consideration, would be naturally divided into five or six loosely defined periods or stages. The first period should be devoted almost exclusively to observation and drawing representations of the things observed. The whole effort should be to acquire the habit of accurate, and to discourage cursory, observation, and also to attain some skill in depicting simple objects.

The second period should be an expansion of the previous one, both as to scope and detail, and should include exercises to cultivate clear visualisation; also exercises which would increase the ability to recall all those things which naturally group around a given object.

The third period, continuing and amplifying the foregoing manual training, should now assume a prominent place (though commenced earlier), and tools be introduced; also drawing involving precision and drawing tools, and exercises involving inference and simple analysis relating to concrete things, their form, material, structure and function. The physical organs of the senses, touch, taste, smell, hearing, seeing, should all receive careful training with gradually increasing rigour, commencing in the previous periods, also the faculties of judgment or comparison, by exercise in estimating size, number, weight, strength, etc., of things and material. Elementary science, simple arithmetic, reading and writing may be acquired in this period, but no particular emphasis need be placed upon the last two.

In the fourth period, continuing the manual and sense training, physical geography, geometry, arithmetic, may be emphasised so far as can be without the use of books, and derived from, and applied to, the objects concerned in the cultivation of manual skill. Exercises pertaining to concrete matters involving inference, elementary synthesis and analysis should receive particular attention. Books may be used sparingly during this period.

In the fifth period, arithmetic, geometry, political geography, grammar, history, languages, and other studies involving abstract ideas and the use of books, may be introduced. Logical reasoning; problems involving unknown quantities; systematic training in contriving means for accomplishing definite ends and devising novel and useful constructions, etc., should receive attention. To the end of the course, special emphasis should be placed upon the cultivation of logical reasoning with the direct object of cultivating individuality and personal initiative. Specialisation may now be commenced very gradually and carefully.

The sixth period should be devoted to learning a specific trade, art, profession, or calling in as specialised a manner as may be, and as nearly as possible under conditions of commercial necessity. The elements of time, cost, and utility should be given their proper consideration. At the completion of the educational course every individual young man or young woman should be a productive member of society, competent of self-support, at least.

A discussion of the question as to whether it is within the province of a non-paternal government to teach arts and trades would take us too far afield. I would only suggest that if it is within the province of such a government to teach to a certain portion of its youth the art of war and destruction, for its preservation, then it is not illogical to cultivate and promote in the remainder the knowledge of the arts of peace and construction with the same object.

The subject of systematic physical culture has been omitted in my outline, though not from lack of appreciation of its necessity. On the contrary, it is so obvious a necessity that the needed space to enlarge on this part of the subject has been devoted to amplifying less obvious phases of the question. A healthy mind in a healthy body is the ideal result of education, and, of course,

this cannot be attained if one of the two factors be ignored.

It will be observed that the underlying idea of the course outlined is based upon the assumption that a child is an incomplete, though growing and developing, organism. The object aimed at is to assist growth and development. Think of a man whose faculties have been trained from infancy up to see with precision, to perceive with accuracy fundamental relations, to reason logically, and whose hands are skilled to respond unerringly to mental impulse. Is he not equipped for life's battles in a manner which no mere scholarly attainment can equip him?

The battles of life are won not by what a man knows, but by what he can *do* and *does*.

CORN AS FUEL.

By Professor C. R. Richards.

THE cost of fuel for manufacturing operations, or for domestic use, is considerably greater in many of the Western States of America than in other sections of the country possessing an abundant supply of coal. Manufacturers thus find it difficult to compete with other firms that can secure cheap power, while in the household the cost of fuel is a very large item in the yearly expenses. The almost entire absence of a natural fuel supply, together with excessive freight rates and little competition, are largely responsible for this condition.

As is to be expected in a treeless and coalless country, the farmers of the American West have used for fuel anything that is available,—buffalo and cow chips, hay, straw, corn stalks, cobs, and lastly, corn itself. This is another illustration of the ability of man to adapt himself to his surroundings, and to utilise what he has for what he needs. It is difficult to say at what time corn was first burned, but it has probably been used to a greater or less extent for a good many years. Dire necessity drove the early settlers to this practice, and the results were sufficiently good to warrant its continuance.

In a general way, it has been recognised that when corn is abundant and cheap, and coal is expensive, the former makes a cheaper fuel than the latter, although no scientific determination of their relative efficiency has ever been made, so far as the author is aware. During the past winter, however, a number of inquiries were received by the Department of Agriculture of the University of Nebraska, asking for information about the efficiency of corn as fuel, and the author undertook the investigation of this subject. The result of the first tests were published in a press bulletin, issued by the experiment station of the university early in January of the present year.

Later in January, the State Board of Transportation of Nebraska addressed a circular letter to grain and coal dealers throughout the State, asking for conservative estimates of the number of people in their vicinity who were burning corn. This investigation was undertaken to secure data for an attempted readjustment of existing freight rates on corn and coal. Many of the replies to these letters are of interest, and the author takes the liberty to quote from some of them. It would otherwise be difficult to believe that so many have

used corn for fuel during the past winter.

In a letter from Battle Creek, Neb., it is stated:—"The farmers are buying no coal at all. Those who bought coal in the past are now burning corn. My coal trade is confined to the town, and to a few school districts, but this has fallen off 50 per cent. since corn touched ten cents per bushel."

From Petersburg, Neb., comes the statement:—"All farmers in this vicinity are using corn for fuel. We sell coal, but our former customers are now burning corn." From Pleasanton, Neb.:—"At least three-fourths of the people in this section are burning corn." From Rising City, Neb.:—"All the farmers are burning corn. They say it is as cheap as coal. Some claim they have burned as much as two hundred bushels already." From Ulysses, Neb.:—"We think there will be 15,000 bushels of corn burned in the district tributary to this town, or in other words, sixty bushels to every quarter section of land." From Meadow Grove, Neb.:—"Our farmers are burning corn almost to a man. I don't think I have sold to exceed five tons of coal outside of town this winter. Farmers say they cannot afford to sell corn for seven to nine cents per bushel, and buy coal for seven dollars per ton, that being the price of Rock Springs coal, which is sold here altogether." From Prosser, Neb.:—"There is no doubt but that nine-tenths of our farmers are burning corn, and so far as I can see, from a financial standpoint, it is the right thing to do. . . . We are using it in our schoolhouse."

Most of the other letters contain essentially the same information as the foregoing. From all of them it appears that a large percentage of the people in Nebraska use corn as fuel when the crop is abundant and the price low, and we may naturally infer that the same condition prevails in some of the other Western States. It is an unfortunate fact that in most of the sections where the value of corn is least, the cost of coal is greatest. From a sentimental standpoint, it must be a difficult matter to burn corn, but from an economical standpoint it is merely a question of money.

The earlier tests of corn, previously mentioned, were made to compare the heat of combustion of corn with that of Rock Springs, Wyo., coal, which was thought to be most largely used in Nebraska, especially in the western part.

Two boiler tests were made, the first, an eight-hour test of corn, during which 5232 pounds were burned; the second, a six-hour test of Rock Springs coal, during which 1888 pounds were consumed. The results of these boiler trials showed that the coal gave 1.9 times as much heat as the corn.

A good grade of yellow dent corn was used in this test. It had been husked but a short time before, and contained a large amount of moisture, which was not taken into account in the test. No determination of the actual percentage of moisture was made, although it is probable that it was not far from 20 per cent. The Rock Springs coal is an exceedingly free burning, non-caking, bituminous coal, containing a very small percentage of ash. This coal costs, in Lincoln, $6.65 (£1, 6s., 7½d.) per ton.

After having completed the boiler trials, samples of the coal and corn were burned in a fuel calorimeter. The heat of combustion of the corn was 7076 British thermal units, and of the coal, 13,010 units. The ratio of these results, 1.86, agrees very closely with the ratio obtained in the boiler trials.

These first tests demonstrated that the particular kind of corn used must be worth 12¼ cents per bushel to cost as much as the Rock Springs coal, not including the cost of hauling the corn to market and of returning with the coal.

Before giving the results of the second series of tests, a brief description of the calorimeter employed in these trials may be of interest. The apparatus consists of a bell, or bottle-shaped glass combustion chamber, 2¾ inches in diameter, and 4 inches high. The bottom is open, and the mouth is closed by a rubber stopper with a small glass tube running through it, down about an inch into the bottle. A metallic base may

be attached to, or detached from, the combustion chamber by three brass spring clips. In the centre of the base a short piece of brass tubing is soldered, forming a receptacle for a platinum crucible in which the combustion of the sample of fuel takes place. A copper can, or jar, about 5 inches in diameter and 12 inches high, contains water in which the calorimeter is plunged during combustion.

Two grams of powdered fuel are placed in the crucible, together with a short piece of cotton fuse. The fuse being lighted, the glass combustion chamber is placed on the metallic base, and the whole calorimeter is plunged into the can, containing 2000 grams of water, oxygen gas under slight pressure being introduced into the combustion chamber through the glass tube. As the fuel burns, the products of combustion pass directly through the water, imparting their heat to it. The total rise of temperature during combustion is directly proportional to the heat liberated by the sample tested. A correction for the specific heat of the apparatus is necessary. This can best be determined by burning pure carbon in the calorimeter, which, according to Berthelot, gives up 14,646 B. T. U.

All calorimeters are liable to slight error, due to all or a part of the following conditions:—(1) Inaccurate weights of fuel or water; (2) Incomplete combustion; (3) Radiation or absorption of heat; (4) Inaccurate thermometer readings; (5) Incomplete absorption of the heat of combustion by the water. Some other forms of calorimeters may be liable to other distinct errors. Some of the sources of error mentioned may neutralise each other. The form of calorimeter used by the author is not so accurate as some of the more elaborate instruments, but it gives results which are probably within a small per cent. of the correct ones.

In making later tests it seemed desirable to determine the heat of combustion of corn on the ear, and also of the grain and cob separately, both of yellow dent and of white dent corn. The various samples were ground as fine as possible, and were then burned in the calorimeter. Each kind of corn was tested from two to five times, to insure more accurate results. The principal difficulty experienced by the author in making these calorimeter tests was to secure complete combustion of the sample. The combustion at times proceeded with explosive violence (once the calorimeter was blown up), and small unconsumed particles of the corn were probably blown out. The samples of cob were the most troublesome of all. In view of this difficulty to secure complete combustion, it seemed desirable to take the highest reading in the various series of tests as the correct one, rather than to assume that the average of all readings would most nearly represent the actual heat of combustion. This seems the more desirable, because in nearly every case the thermometer reading was highest when the rate of combustion was slowest,—that is, when there were fewer explosions.

From the results of the calorimeter trials, and from the results of a number of analyses, the following table of the heating value of corn is calculated, the figures all being British thermal units. The marked difference between the heat of combustion in the earlier and later trials is due to the greater percentage of moisture in the samples used in the earlier trials.

THE HEATING VALUE OF CORN.

Kind of Material.	Heating Value in B. T. U. Per Pound of Material.	Per Pound of Dry Material.	Per Pound of Dry Combustible.
Yellow Dent Corn and Cob	8,040	------	------
Yellow Dent Corn	8,202	8,959	9,085
Yellow Dent Cob	7,214	7,841	7,958
White Dent Corn and Cob	7,841	------	------
White Dent Corn	8,382	9,199	9,301
White Dent Cob	7,571	8,174	8,285

The average heating value of the coals in use in Nebraska is not far from 11,500 B. T. U. Assuming this value, and taking the heating value of yellow dent corn on the ear as 8040 B. T. U., the following table has been computed, showing the cost of corn per bushel to

equal that of coal, selling at different prices:—

Cost of Coal per Ton.	Cost of Corn per Bushel.
$2.00 (8sh)	4.9 cents. (2.45d.)
2.50 (10sh.)	6.1 " (3.05d.)
3.00 (12sh.)	7.3 " (3.65d)
3.50 (14sh.)	8.5 " (4.25d.)
4.00 (16sh.)	9.8 " (4.90d.)
4.50 (18sh.)	11.0 " (5.50d.)
5.00 (£1)	12.2 " (6.10d.)
5.50 (£1 2sh.)	13.4 " (6.70d.)
6.00 (£1 4sh.)	14.7 " (7.35d.)
6.50 (£1 6sh.)	16.0 " (8.00d.)
7.00 (£1 8sh.)	17.1 " (8.52d.)
7.50 (£1 10sh.)	18.3 " (9.15d.)
8.00 (£1 12sh.)	19.5 " (9.75d.)

In many cases liquid fuels are somewhat more desirable than solid fuels, on account of the absence of ash and smoke, and the greater ease of regulation of combustion. Alcohol, the liquid distillate of corn, is admirably adapted for a fuel, could it be produced cheaply enough to be used in this way. The heat of combustion of alcohol is given by Professor Carpenter as 12,700 B. T. U. per pound, and by Professor Cooke as 12,931 B. T. U. A certain amount of heat produced by the combustion of alcohol would probably be more economically used than a like amount of heat produced direct from the corn, since it could be burned in such a way as to turn a greater number of heat units into useful work than with the solid fuel.

A letter from Mr. W. F. Fahs, secretary of the Willow Springs Distillery, of Omaha, states that 1.64 pounds of corn will yield, by their process (an electrical one), one pound of alcohol. The United States government estimates that one bushel of corn (56 pounds) will produce 33¼ pounds of alcohol,—about 1.7 pounds of grain for each pound of alcohol. In assessing the output of a bushel of corn, however, the government makes an allowance of 20 per cent. from this amount for poor grain, accidents, etc., and taxes must be paid upon this basis, even if the output be less than this; if a greater output be produced, the tax must be paid upon all of the spirits.

The heating value of yellow dent corn is 8202 B. T. U., or, 1.7 pounds of corn will liberate 13,943 B. T. U., which is 1012 B. T. U. more than would be given up by the alcohol produced from the corn. This loss could be partially regained by burning the refuse from the process of distillation. Seven pounds of alcohol constitute one gallon, which costs, if the duty be taken off, from forty to fifty cents (1s. 7½d. to 2s.). It is thus evident that its cost will prevent the more extensive use of alcohol as fuel.

From the experience of the author in conducting the boiler tests of corn, it is doubtful whether it would be a practicable fuel for the generation of power, unless it were burned in some special furnace that would insure the perfect combustion of the volatile matter which forms so large a percentage of the whole corn, and which is driven off at a comparatively low heat. Some form of automatic stoker would also be desirable, since the corn burns rapidly and must be frequently fired, making the work of the firemen very arduous, and at the same time tending to cause incomplete combustion by the excess of cold air entering through the fire door.

Undoubtedly corn may, at times, be a cheap and economical fuel for domestic use. It is cleaner and more easily handled than coal, and contains but a very small amount of ash. It burns rapidly with an intense heat, which is apt to be destructive to the cast iron linings of the stove. Here, again, some special form of fire-box, that will not be injured by the heat, and that will utilise as much of the heat as possible, should be used. If the rate of combustion be too great, much of the heat will pass up the chimney.

It is interesting to note that an acre of land will produce from 40 to 80 bushels of corn, which, if burned, will yield from 22,512,000 B. T. U. to 45,024,000 B. T. U., not counting the heat that could be obtained from the stalk. Since a ton of good coal will give up from about 20,000,000 to 26,000,000 B. T. U., an acre of ground is each year capable of producing fuel which is equal to from 0.87 or 1.28 to 1.74 or 2.56 tons of coal. The stalk will probably increase this amount by one-fourth or one-third.

ELECTRIC POWER IN A GREAT RAILWAY SHOP.

AN INTERVIEW WITH F. W. WEBB, CHIEF MECHANICAL ENGINEER OF THE LONDON AND NORTH WESTERN RAILWAY.

THE fame of the great shops, at Crewe, of the London and North Western Railway is international. Engineers in all countries have, for years, looked to it as one of the world's greatest industrial establishments,—a place of methods and machinery typical of the most advanced practice in railway engineering,—and many have reaped benefit from its store of accumulated experience.

The works date back to 1843, when about 150 men formed the beginning of a working population that since then has grown to nearly 20,000, toiling unceasingly for the maintenance of a great railway system. To them Mr. Webb came in 1851, as a pupil, and rose successively through various grades until, finally, he attained the important and dignified office which he now holds.

During Mr. Webb's works administration engineering development in all branches was extraordinarily rapid, and the establishment at Crewe was quick to seize whatever advantages were offered by the march of progress. Not the least important among these were the various uses of electricity, and, in the course of a recent conversation, Mr. Webb referred

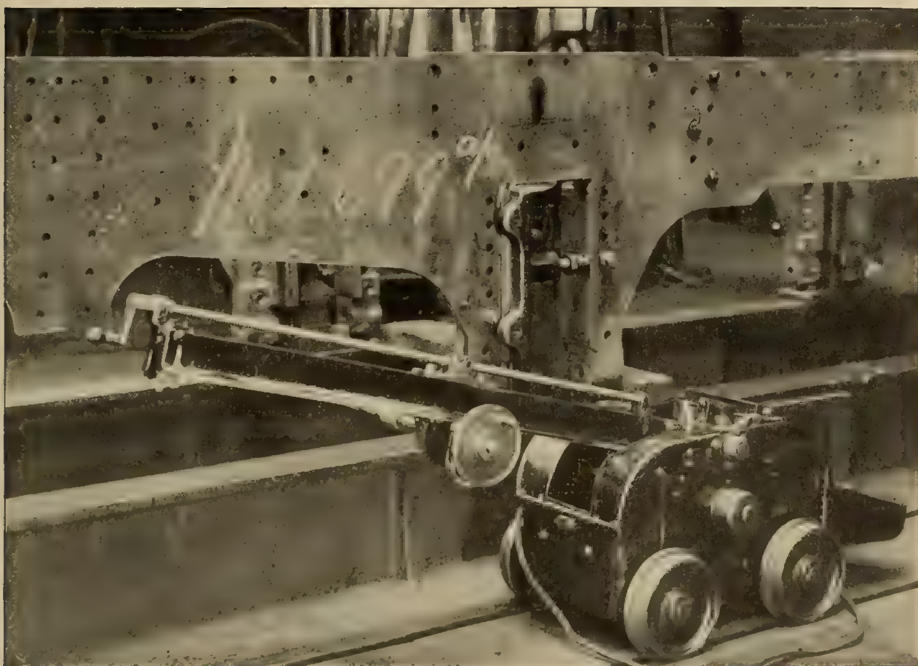


FIG. 1. AN ELECTRICALLY-DRIVEN DRILLING MACHINE

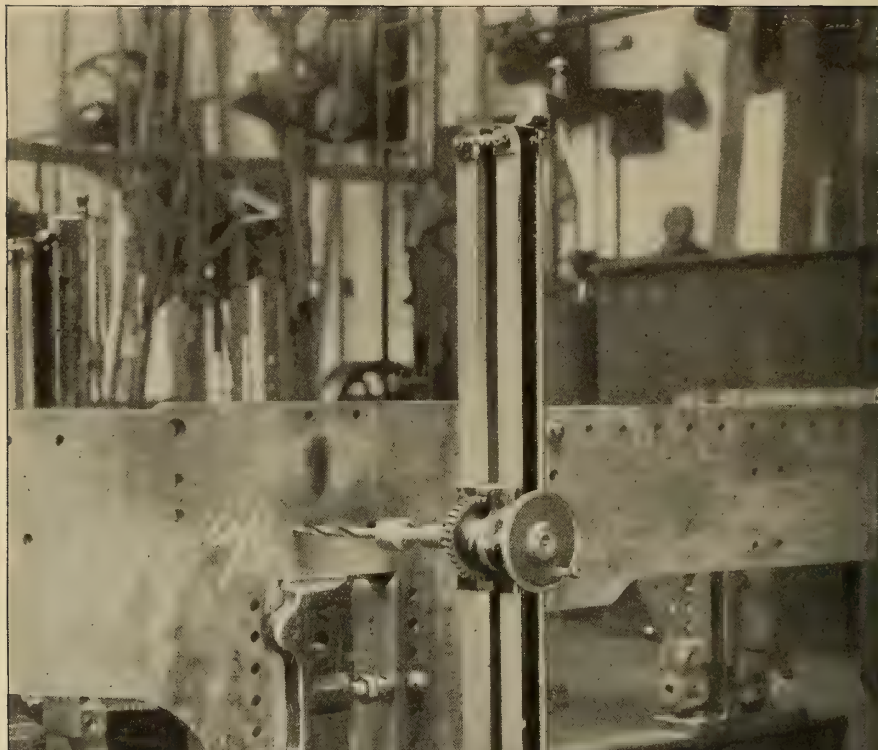


FIG. 2. TRUING HOLES IN LOCOMOTIVE FRAMES.

to the good service which he had obtained from the newer power, especially as applied to portable tools.

"The electrical department at the Crewe shops," said Mr. Webb, "was instituted about seven or eight years ago for the purpose of dealing with the electric lighting of the company's stations; but in addition to this electric lighting, which is the chief work of the department, some interesting applications of electric power, in lieu of hand-worked tools, have been carried out, work which could not satisfactorily be dealt with before the perfection of the dynamo, because of the necessity of having considerable power in a portable form. For instance, a small portable drilling machine which we have in use here develops about 1 H. P. and weighs a little over 50 pounds, the small electric motor which actuates it running at some 3000 revolutions a minute.

"This little tool," Mr. Webb went on, referring to photographs which have been reproduced in Figs. 1 and 2, "is used principally for rosebitting, or, in other words, truing the holes in the frame plates of locomotives when on the erecting frames,—work which had previously to be performed by hand, or partially by flexible shaft, as a fixed tool could not, of course, be utilised for the work. In this case the little electric motor, which develops about 2½ H. P., is carried on a small carriage which enables the tool to be rapidly run to any part of the shop where it may be required.

"Perhaps one of the most interesting of the many labour-saving tools of this nature introduced in the shops is the tube cutter (Figs. 3 and 4). A large number of these cutters are in constant use in the Crewe Works, effecting a great saving of time. In re-tubing a locomotive boiler, which contains 200 tubes, more or less, the old tubes have to be cut out and the work has hitherto been performed by hand,—necessarily a very slow process. The cutter takes the form of a small saw, about one and a

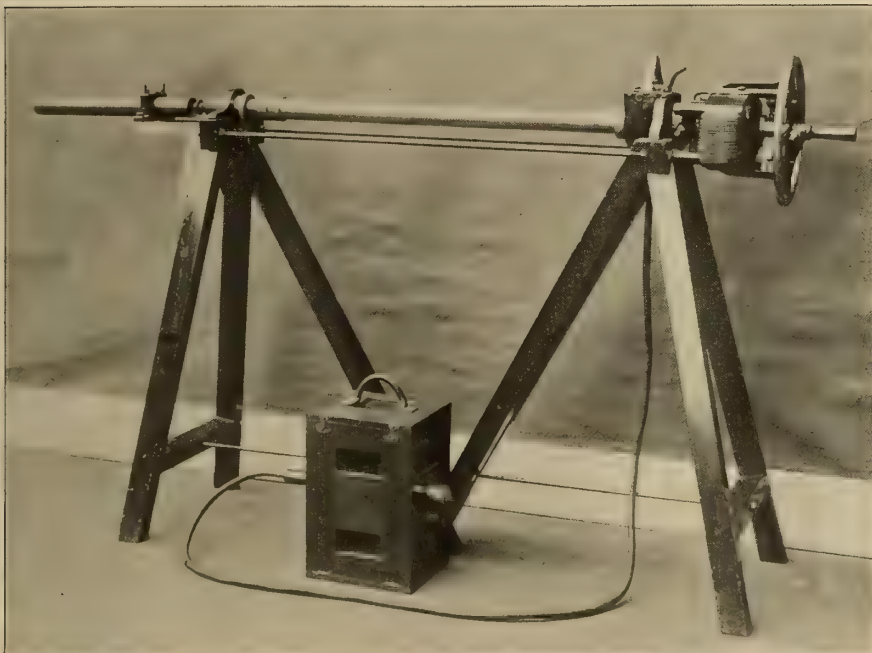


FIG. 3. AN ELECTRIC TUBE-CUTTER.

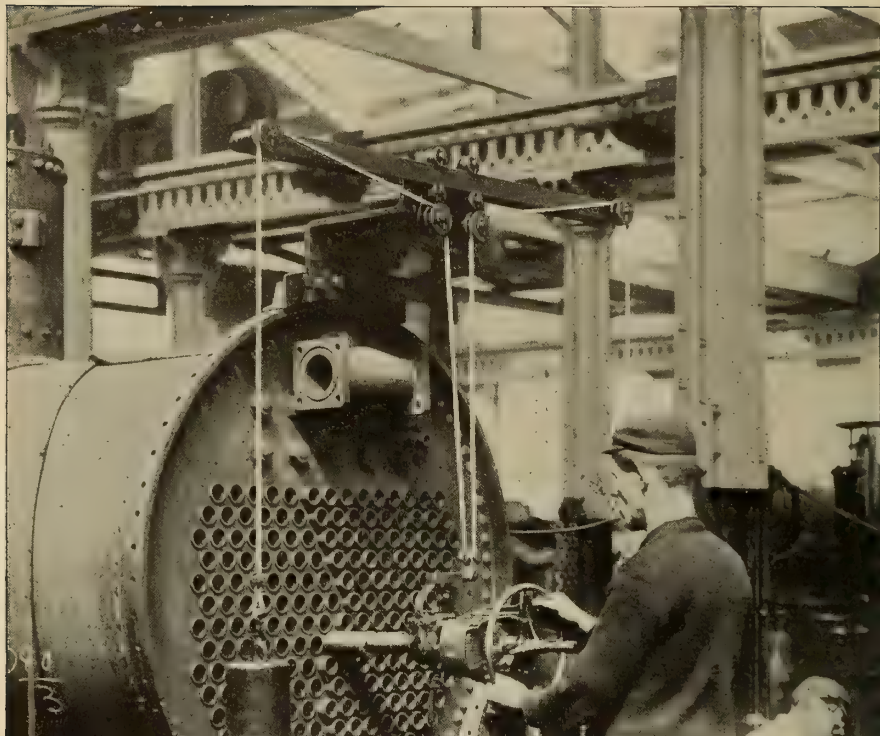


FIG. 4. ELECTRIC TUBE-CUTTER IN OPERATION.

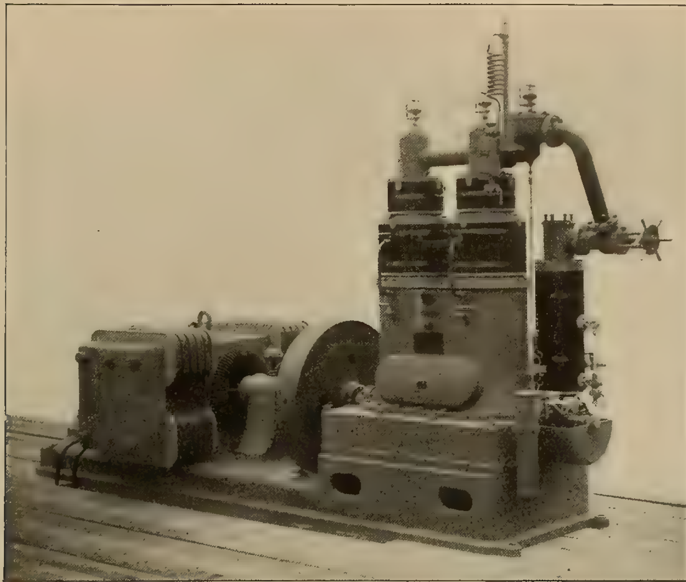


FIG. 5. DIRECT-CONNECTED CREWE DYNAMO AND ENGINE BUILT BY MESSRS. WILLANS & ROBINSON, LTD., RUGBY.

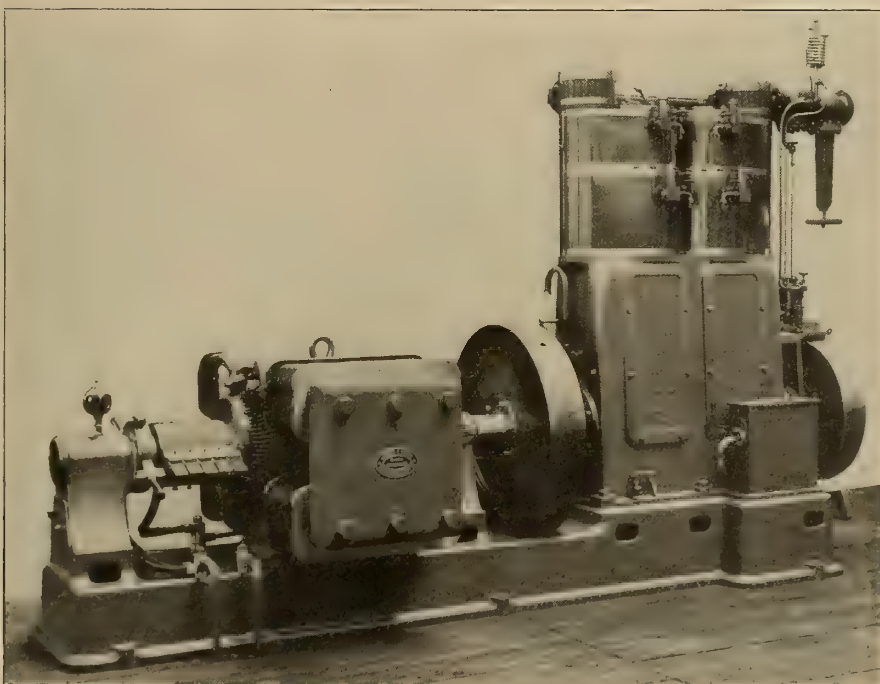


FIG. 6. CREWE DYNAMO AND ENGINE BUILT BY MESSRS. BUMSTED & CHANDLER, HEDNESFORD.

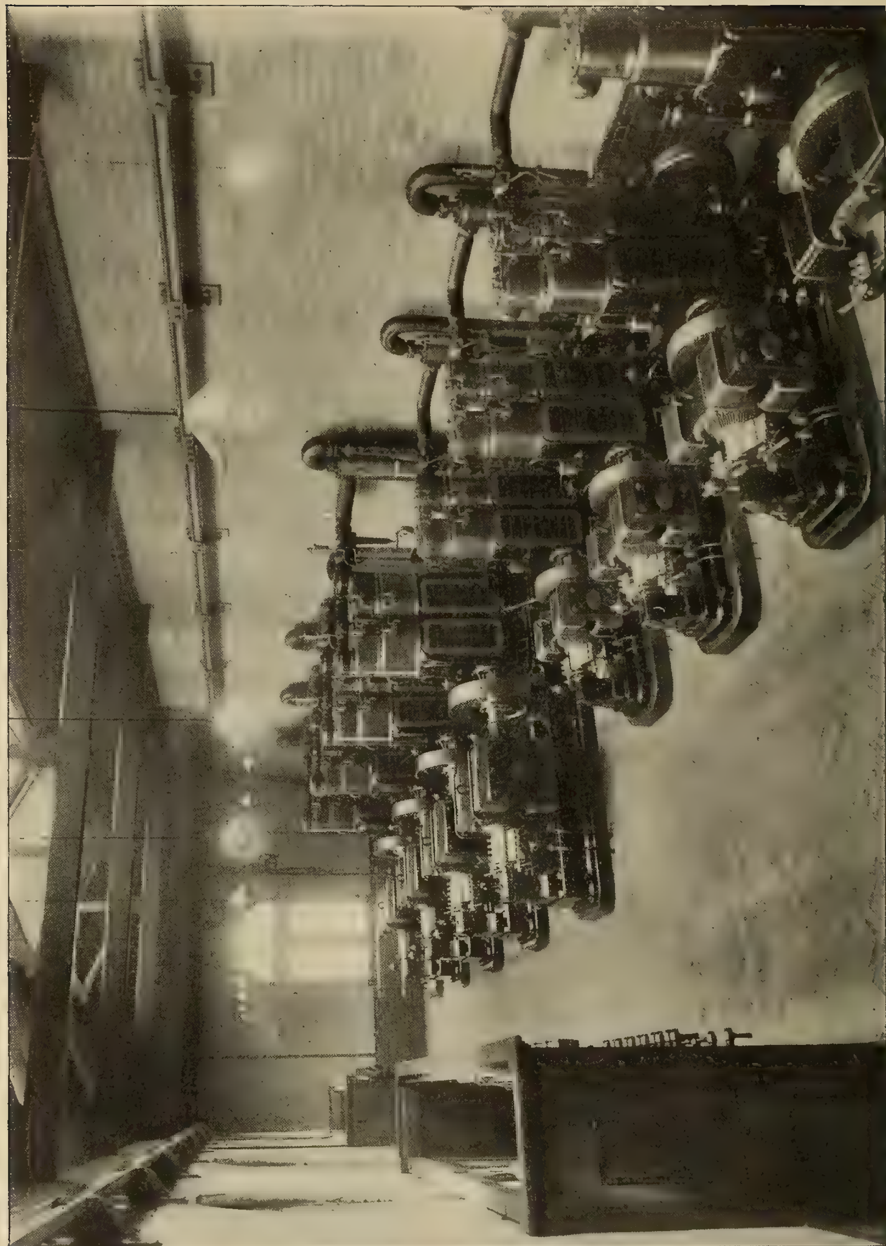


FIG. 7. DYNAMO ROOM FOR LIGHTING A LONDON & NORTH WESTERN RAILWAY GOODS AND PASSENGER STATION.

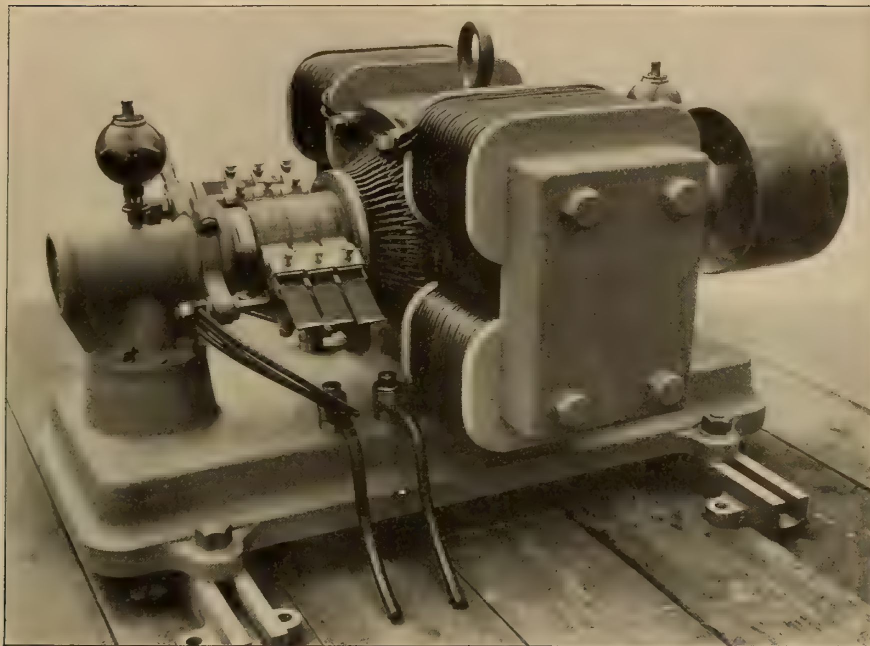


FIG. 8. A STANDARD CREWE DYNAMO.

half inches in diameter, and is driven by a small motor developing about 2½ H. P. at a speed of about 3000 revolutions a minute, the tubes being cut at the rate of about three in a minute. The same tool also cuts the new tubes to the exact length required while in their place."

"Has electric driving been applied to any of the heavier shop machinery?" occasion was taken here to ask.

"Yes," replied Mr. Webb. "In addition to these portable tools, some ten or twelve electrically-operated cranes have been fitted up in the works, varying in lifting capacity between 4 and 30 tons. In each case a small electric motor is provided for each of the three movements of the crane, and the result has proved itself to be much superior to the old system of quick cord driving."

As to the dynamos and motors in use at the shops, Mr. Webb remarked:—"We have kept in view the importance of having them all of one standard pattern. About one hundred machines of this pattern, of various sizes, have up to the present been constructed. The magnets are cast in mild steel manufactured at Crewe, which has a permeability equal to the best wrought iron. The armatures are of the Gramme type, wired with compressed cable, laid in slots. For electric lighting work the dynamos are coupled direct to high speed engines."

Pulling out a cabinet drawer of photographs, he handed us one of the pic-

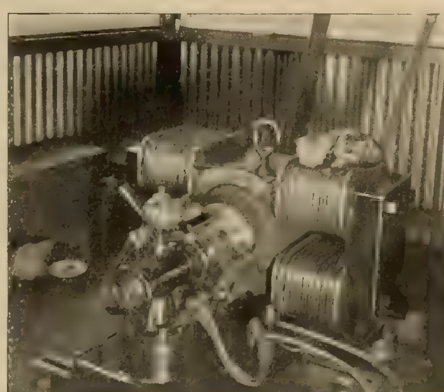


FIG. 9. ANOTHER VIEW OF ONE OF THE SHOP DYNAMOS.

tures. "That," he said, "shows one of our dynamos coupled to a Willans engine (Fig. 5), and this (Fig. 6) is fitted with a Chandler engine. This latter combination, in a smaller size, has been used in connection with the lighting of the company's steamships."

Turning over a number of photographs in quick succession Mr. Webb stopped at the one marked Fig. 7. "This," he explained, "illustrates a dynamo room recently completed for the lighting of one of the company's large goods and passenger stations, the machinery having an output equal to 4000 incandescent and 120 arc lamps. This other one (Fig. 8) shows a standard Crewe machine of a smaller size used for generating the current for driving electric cranes. These machines are belt-driven, at 1500 revolutions a minute, and have an output of 200 ampères at 115 volts."

The photograph from which Fig. 9 has been reproduced has a peculiar interest, showing a cat asleep on the machine. With a twinkle in his eye, and anticipating, perhaps, a question about to be put, Mr. Webb said:—

"No. Mistress Puss has not been purposely placed in this position with a view to increasing the electrical efficiency of the machine. The explanation is simply that, supremely indifferent to what would appear to be a very dangerous experiment, and quite regardless of a rapidly revolving armature, she regularly enjoys her afternoon siesta on the bobbin of the machine, finding, perhaps, a soothing warmth from the electrically heated wire."

But electricity does not end its work at Crewe with what has been shown in the pictures here. Amongst many other minor applications is a complete telephone installation which Mr. Webb has fitted up throughout the works, thus placing all parts in electrical communication, and not only greatly facilitating the conduct of the business, but dispensing with quite a small army of messengers which had to be employed previously.

In the large range of offices attached to the works the clocks, too, are worked electrically, a regulator transmitting the time to all parts of the building every half minute.

NON-FLAMMABLE WOOD.

By Charles E. Ellis.

From a paper recently read at the International Congress of Naval Architects and Marine Engineers at London.

AN experiment which was recently made in London, with the consent of H. M. Office of Works, has drawn public attention to a novel method of rendering wood incapable of flaming or transmitting flame.

As long ago as 1625 a patent was granted by the English Patent Office to one Beale for "a dressing for shippes and other vesselles as the mastes, deckes, tackles, sayles and other furnitures, that they maie be preserved in fight at sea from burning or consumynge by wildefyer or gunpowder."

From that period forward countless efforts seem to have been made to obtain the desired result, but most of the experiments appear to have been conducted on the lines of soaking or coating timber with various preparations, and no plan seems to have been devised for securing what is absolutely essential, namely, that the fire-resisting treatment shall permeate the heart of the wood so as to render it internally as well as externally fire-proof.

The earlier inventors naturally lay under great disadvantages. Little was known of the chemical and physical qualities of wood, which, when they are thoroughly understood, appear to point to the practical solution which has been obtained under the discovery now under notice.

The various kinds of timber vary much in analysis, but (taking an average) wood may be said to contain about 40 per cent. of water, 58 per cent. of combustible elements, and nearly 2 per cent. of incombustible elements, or ash, comprising various salts of lime, potash and the like. In structure it consists of a number of cells or vessels, varying also with every kind of wood, in or around which the combustible materials above referred to are contained.

It is obvious that the main difficulty of getting rid of the combustible elements and substituting others lies in providing means for treating the cells without rupturing their delicate structure, and so deteriorating the value of the timber.

It is claimed for the new non-inflammable wood that this difficulty has been successfully overcome. By this process the timber is placed in a cylinder and a vacuum is formed. Steam is then admitted, causing the moisture in the wood to vaporise, the products of the vapour being drawn off. A vacuum is again formed, and the saturating liquid, containing certain salts, is forced in fine spray mixed with steam into the cylinder, until the wood is thoroughly impregnated. The wood is then dried, and is ready for use. The salts which are thus forced into the wood by the process of saturation retard the rapid carbonisation of the wood under high heat, and particularly the generation of combustible gases, which are the cause of flame.

That wood so treated is incapable of supporting or conveying flame was conclusively proved at the experiment above alluded to. Two buildings were erected, similar in design, one being built of ordinary and the other of treated wood. They were about eleven feet square,

with the floors about four feet from the ground, the lower portions of the walls below the floor being formed of open trellis work, so as to allow of circulation of air and flame. The height of the buildings was about thirty feet from the ground to the top of the wooden chimney. The framework and walls were constructed of pine, internally fitted with linings of ash, oak, birch and mahogany. Equal quantities of dry wood, saturated with petroleum, were piled to windward of each building and simultaneously ignited. The untreated building was ablaze in a few minutes, and in half an hour was completely destroyed. The treated building, on the other hand, showed no signs of burning, except where the trellis work and walls were charred by actual contact with the flames from the burning firewood. On entering the building at this stage it was found to be quite cool inside, both on its walls and floor.

A further test was then made of the treated building by igniting a large heap of shavings and firewood inside the structure. By means of open doors and windows and the high open chimney shaft a strong draught was created. The flames from the burning wood rushed up through the chimney, melting the glass in the windows, the fire burning furiously for about twenty minutes. On entering the building it was found that it had been charred, as in the previous experiment, but that, structurally, it was quite uninjured. A box made of treated wood, which had been inside the house during the fire, was also found externally charred, but its contents remained in perfect condition. The success of the experiment above described was apparent to all who witnessed it.

Similar trials have been made in the United States. A number of laboratory tests on a small scale have also been made; but in view of the results given by the severe practical demonstrations above referred to, it is sufficient to say that they fully confirm the conclusion that the treated wood is absolutely incapable of transmitting flame. In all cases the results are identical, while with the fiercest fire local carburisation only is caused.

Before dealing with the use of such wood in naval architecture it may be desirable to refer to a few of its characteristics. The treated wood weighs from 8 to 15 per cent. more than ordinary wood of the same kind, the increase of weight varying with the character of the wood employed. In some cases it takes a slightly deeper colour, but its general appearance is identical. There appears to be no considerable difference in working it, and, like ordinary wood, it is capable of receiving a high polish. So far as experience goes the treatment is of a permanent character. Pieces of wood have been tested after a lapse of two years since the treatment, and found to possess all the non-flammable qualities, and in the opinion of eminent chemists, lapse of time cannot diminish the incombustibility of the wood, since stability and non-volatility are the characteristics of the chemicals employed.

It is also stated by experts that the process of saturation has a valuable preservative action, and that wood treated by the process will be largely protected from dry rot, insects, etc. That this is at least probable is evident from the consideration pointed out by Laslett—that it is the combustible elements of timber which affect its durability, not only by their liability to oxidise in the open air, but by reason of there being the very elements which are consumed by various insects and fungi and other organisms which destroy the wood. A process, therefore, which consists in the treatment of timber in the manner described would appear *ā priori* to be as efficacious in its preservative effect as in ensuring incombustibility.

From the foregoing remarks it would appear that, while on the one hand no practical objections arise to its use, the so-called non-flammable wood in no way belies its name, and in a most important particular is probably more suitable than ordinary timber. It is for the naval architect to decide whether, and to what extent, wood so treated should be utilised in shipbuilding. The arguments

for its use rest on two grounds:—(1) As being non-flammable, it is obviously so far at least superior to ordinary wood; (2) by reason of its low conductivity of heat it may be most usefully employed in substitution for material with greater conductive power.

With regard to (1), the risks of fires at sea are so terrible that little need be said on this part of the case. As to the danger of fire in naval warfare, it is not necessary to go back further than the battle of the Yalu. Mr. H. W. Wilson, in "Ironclads in Action," points out that the number of fires which occurred on board the ships of both combatants was a striking feature of that battle. The *Lai Yuen* was so severely burnt that nothing but her ironwork remained above the water-line. The *Ting Yuen* and the *Ching Yuen* were on fire three times, the *Chen Yuen* eight times, while four other vessels were on fire at least once.

"The Japanese," says Mr. Wilson, "suffered somewhat from fire, though not so seriously as the Chinese. Doubtless their ships were in better order, and discipline on board them was more thoroughly maintained. It is also probable that less wood was used in the construction of their vessels. The fires seem to have been the effect of gunpowder alone."

It may naturally be said that with better discipline such fires could not have assumed such serious proportions. No doubt this is so, but the main point remains that, if a fire breaks out in a naval engagement, men must be drawn from their ordinary duties, whether from the stokehold or gun batteries, or elsewhere, to put the fires out, thus creating considerable disorganisation, and possibly panic. I am, of course, aware that in the most modern vessels of war the substitution of metals for wood has reduced the danger of fire possibly to a minimum; but I shall await with interest the opinions of those best qualified to judge as to whether it would not be desirable to revert to some extent to the old material now that the danger of fire is practically over.

The Navy Department of the United States has already specified that all wood used in the construction of vessels recently ordered—I believe about thirty in number—shall be treated by the new process, and the Japanese Government, who are always desirous of embodying in their designs any modern improvement, have also specified the treated wood for all timber used in the construction of the two new cruisers now building in American shipyards.

The second point above alluded to, namely, the low degree of conductivity of wood, points to its use in many cases where hitherto wood could not be used on account of the danger of fire. I may instance ammunition boxes, particularly where they contain smokeless powder, which, as is well known, is of so sensitive a character as to be materially affected by changes of temperature. It is also suggested that cylinders, and even boilers, might be cased with the wood, and thus materially increase the efficiency of the steam service, and further conduce to the comfort and health of the men on board. In this connection it is of interest to note that, in experiments that have been recently made, it was shown that the conductivity of treated wood was about 50 per cent. less than that of ordinary wood of the same kind.

Great radiation of heat is necessarily consequent on the use of metals, and it is submitted that many uses may be found, whether on war, passenger or cargo steamers, for a material of less conductivity. In the case of ships passing through the tropics, this point becomes one of first importance.

MARINE FEED WATER FILTERING.

By Nisbet Sinclair.

IT is now being more fully and generally appreciated that cleanliness in a boiler means the entire absence of dirt, and that "dirt" is to be understood as Lord Palmerston defined it,—"matter in the wrong place." As nearly as possible there should be nothing inside the boiler but water and steam. In fact, engineers find that they must proceed on the principle of the Chinese doctor and prevent disease by keeping out "dirt" rather than by pouring in correctives, of which little is known, to regulate the conduct of the "dirt," of whose ways the knowledge is still less.

With the greatest care, it is not possible to prevent some oil getting into the steam; rods must be swobbed, and auxiliary engines are a great temptation to an engine tender with an oil can. It is the function of the feed filter to extract this oil and any other "dirt" from the feed water.

Mr. James Edmiston and Mr. Anthony Harris seem to have carried on their independent investigations in feed filtration contemporaneously. The former stated that he worked at the subject as early as 1883, and explained the evolution of his filter in a paper to the engineers of the northeast coast of England, in 1892. He did not, however, describe in detail his earlier experiments. The latter indicated at that same meeting, in discussing Mr. Edmiston's paper, that he had also been long working at the subject, showing in his speech familiarity with its difficulties, and he supplied for this paper a most interesting series of drawings, showing the development of the Harris filter from 1886.

A more exact idea of the work done by the grease filter may be gathered from the following analyses. The first is by Mr. A. Norman Tate, of the deposit from an Edmiston filter:—

Fatty and oily matter, consisting of:—		
Fatty matter	29.96	
Mineral oil	19.42	
Water	29.6	
		78.98
Mineral matter, consisting of:—		
Silica	1.49	
Oxide of iron	16.46	
Lime	0.75	
Copper	2.32	
		21.02
		100.00

The copper appears to be largely in solution with fatty acids.

The following analysis is by Messrs. Pattinson & Stead, of Newcastle, of sludge removed from the Harris filters in the Atlantic mail steamer *Campania:*

Heavy oil dissolved out with ether	55.34
Organic matter insoluble in ether	4.60
Mineral matter left on calcining the residue comprising iron oxides in greatest proportion, copper, zinc oxides, salt and a little sand	20.9
Moisture	19.76
	100.00

In the sample glass feed water from the condenser has a slightly milky or opalescent appearance, and a soapy feeling; after passing the filter it is quite clean. The deposit on the filter cloths and grid wire meshes is a dark, heavy, sticky mud.

These grease filters consist simply of masses of finely divided material, not easily decomposed by feed water, through which material every drop of

feed water is passed and, in passing, is cleared of suspended matter, partly by the "straining" of the minute interstices, and partly by exposure to con-

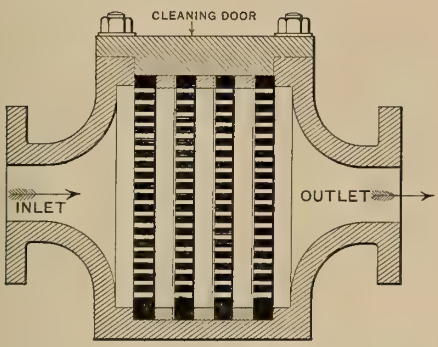


FIG. 1. EDMISTON'S FIRST DESIGN, FITTED TO THE FEED PIPE IN DUPLICATE.

tact with, or the obstruction of, numerous surfaces on which matter that is of greater consistency than pure water adheres. The filtering material gradually becomes laden with the deposit and is periodically cleaned or renewed.

Of course, this filtering process is only a mechanical one, and may pass soluble matter which should not go into the boiler. This part of the subject,—the throwing out of the small remnant of chemical impurities,—belongs to the chemist, and we await his instructions under the provision that his process is carried out, not in the boiler, but before the feed water gets there.

It will be at once appreciated that the effective duration of a filter depends upon the area of the filtering material at right angles to the direction of flow, and that the efficiency of the filtration depends upon the thickness of the filtering material or the number of strata of a given thickness. Thus, we may have filters to last a day, or thirty days, without being cleaned, and we may have, with woven media, one, two, three, or more successive filtrations, or the equivalent in multiple thickness of media in mass.

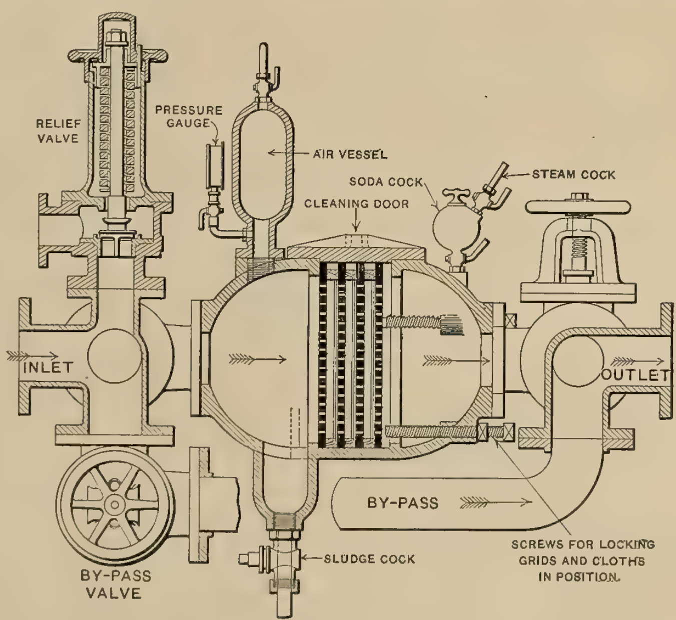


FIG. 2. SECTION OF A LATER FORM OF EDMISTON FILTER.

On board a ship the restrictions of space in machinery rooms render it necessary to make filters small in size, and they generally, therefore, require frequent cleaning. To enable this to be done without stopping the feed, duplicate filters are often provided, for working and cleaning alternately, by-passages and valves being added for use in case of accident.

Then, the location of the filter in the feed system, or in the whole steam system, is important. If the filter is situated where it very often is, between the feed heater and the boiler, the water may be of 250° F. At this temperature some of the oily matter in it is near its vapourising point, and the rest is liquified to such a degree that the greater quantity possibly passes as easily

through the filter as pure water does. Filtration is, in this case, conducted under boiler pressure and the shell, doors and joints of the filter must be made very strong and heavy, thus making the opening, cleaning and closing process laborious. It is true that the filter located thus may be small since a few pounds extra pressure in the pipes, due to the resistance of a foul filter, is

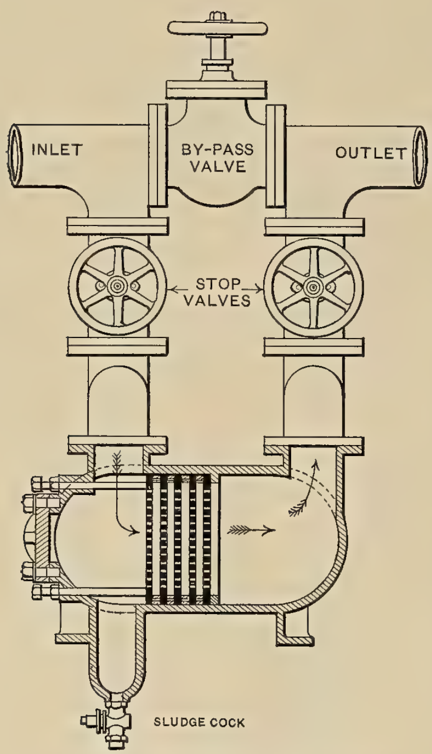


FIG 3. EDMISTON FILTER ON THE ATLANTIC LINER "MAJESTIC."

of little consequence; but the filtration is not effective.

This work should be performed at the lowest possible temperature, for then the oil, grease and other matters are in their most glutinous, viscous or least fluid condition, and some matters in solution at 250° F. may be in suspension at 100° F. The filter, therefore, arrests much more matter than when the temperature is higher. Besides, it is desirable to keep the feed heater, the cold and hot pumps, and as many of the valves and pipe connections as possible, clean by passing only filtered water through them.

The position presenting all these advantages is the suction side of the hot-well or feed-tank pumps, or, in other words, the discharge branch of the feed tank. This location, however, presents the difficulty that since the hot-well usually works under very little "head" of water, the resistance of the filter requires to be overcome by the minus pressure in the sucking pumps, and in view of this the resistance must be restricted to five pounds per square inch or less. This involves either very frequent cleaning or a very large filter.

Counterbalancing the large space occupied by such a filter there are the advantages of a light pressure and light character of structure, as well as the more effective work done. In the smaller class of ships of the British Navy, fitted with the Harris filter, the filter grids are sometimes placed in the hot-well or in the steel feed tank built into the structure of the ship, thus saving the weight of the outer shell of the filter and some space also.

To go a step further and eradicate the grease trouble entirely from all interiors beyond the cylinders, filters are sometimes placed on the exhaust steam entrance to the condenser, and since the auxiliary engines on board are the heaviest users of oil, the auxiliary exhaust piping and auxiliary condensers are more especially guarded by these exhaust steam filters.

There are, however, objections to the use of exhaust steam filters, or rather, to their use to the exclusion of filters at the hot-well; namely, the very high temperature, the inefficient filtration and the very great area of filtering medium necessary to prevent injurious back pressure. Further, the variations of back pressure from clean to foul condition might affect the smooth working of dynamo engines. Objections notwithstanding, however, the thing has been done in many instances, apparently to the satisfaction of the users.

The most practically convenient and desirable compromise of location for the filter appears to be the discharge of the hot-well pumps, or between the hot-well

pumps and the feed heater; for thus the low temperature is secured and the pumps give "head" enough to permit the filter to be placed at any level which the engine room arrangements and its accessibility demand.

Having now described in a general way the purpose of marine filters, or grease extractors, and the conditions under which they are used on board ship at the present time, it may be in order to indicate more in detail the development of their form and structure. Let us take, first, the Edmiston series.

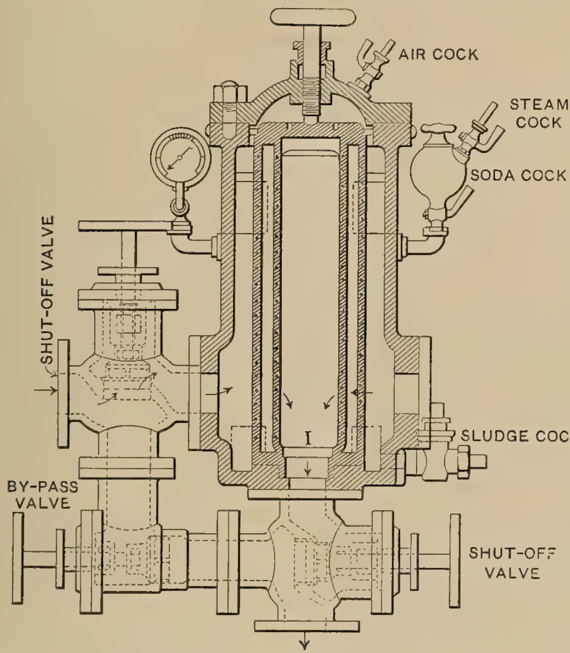


FIG. 4. EDMISTON FILTER WITH DOUBLE CYLINDRICAL GRIDS.

This filter in its rudimentary form is shown in Fig. 1. It is simply a box, placed in the feed pipe, with four rose plates or grids, covered with felt, interposed in the flow, giving, since the water passes four cloths in succession, quadruple filtration.

Figs. 2 and 3 are more mature developments, Fig. 2 being fitted in the South African liner *Scott*, and Fig. 3 in the Atlantic liner *Majestic*, of 18,000 I. H. P. The Edmiston filter has, under the care of Mr. W. J. H. Adam, of the Glasgow Patents Company, Ltd., of Glasgow, Scotland, undergone many modifications as the result of ripening experience, the objects kept in view being strength and lightness of structure, simplicity, rapid cleaning or renewing of filter cloths, and suitability to the various portions and spaces available in different classes of ships.

A favourite in the merchant service is shown in Fig. 4,—a very convenient arrangement in which double filtration is obtained by passing the water from the outside radially towards the centre through two cylindrical and concentric grids, covered with filter cloths. The grease naturally floats towards the top and is found to collect in greater quantity there, leaving the lower part of the cloth comparatively clean and in a condition to pass pure water without much resistance.

Fig. 5 shows a cylindrical corrugated surface, giving a larger filtering area in a given capacity than a plain cylinder does, but only single filtration.

Fig. 6 is a spherical design giving single filtration.

Fig. 7 indicates an arrangement of divided grid, giving double filtration. The water passes in radially between two cloths, axially through them, then across the dividing bar, through the cloth again the reverse way, and out radially on the side opposite its entry. This gives a large amount of filtering area in small volume. This sketch shows how compactness of design can be obtained by the use of a double-faced valve for the by-pass.

The development of the filter in Mr. Harris's experience may be clearly traced in the very interesting set of illustrations beginning with the charcoal filter fitted to the steamer *Kama* in 1886 (See Fig. 8). As it soon became apparent that charcoal was not sufficiently

absorbent this was supplanted by other material. Successive modifications are shown down to 1890,—Figs. 9, 10 and 11.

In 1891 Harris's compound filter was fitted to the steamers *Campania* and *Lucania* of 30,000 I. H. P. It is shown in Fig. 12. In this he passes the water first through a chamber containing sponges compressed between grids. These take the " rough " of the deposit. The water then passes through the filter proper, which is a stack of circular grids and cloths very neatly and compactly arranged, so that the water enters a central tube, passes between the grids in a radial direction and escapes at the circumference.

A feature of the design is a sentinel

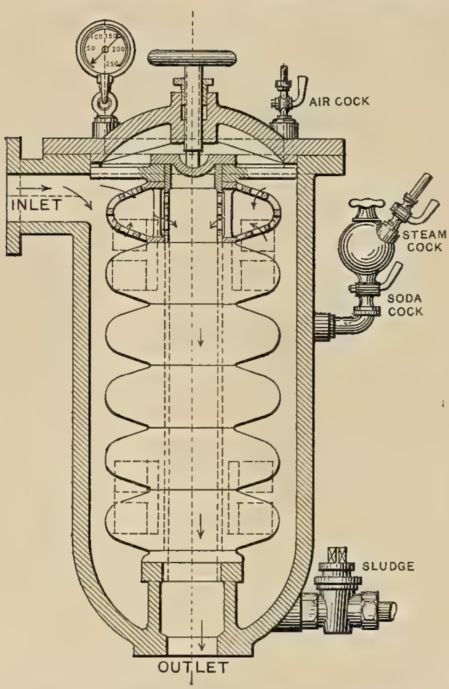


FIG. 5. EDMISTON FILTER WITH CORRUGATED CYLINDRICAL SURFACES.

valve by which the resistance in the filter is limited to a known amount. When this load is exceeded, the spring-loaded valve opens a by-pass to the boiler, the movement of the valve at the same time ringing a bell on the engine platform to warn the engineer in charge that cleaning is necessary.

Fig. 13 shows the latest development for merchant ships. Fig. 14 shows one of two filters of H. M. S. *Terrible*, each equal to a duty of 18,000 I. H. P. Fig. 15 shows the type of filter with alum-

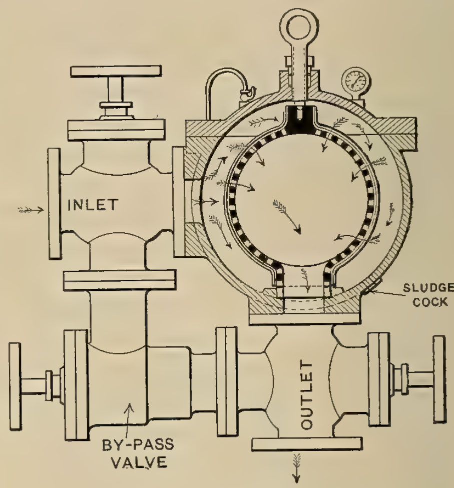


FIG. 6. A SPHERICAL DESIGN.

inium grids fitted into the feed tanks built in the structure of the hulls of the torpedo destroyer class of H. M. ships.

This plan of grid, to which Mr. Harris seems, for the moment, to have settled down, presents certainly a neat and compact way of stowing a large filtering area, and the fact of these being chosen for large ships requiring an effective apparatus, and for so many small ships requiring, as well as filtering efficiency, a sort of *multum in parvo* in the matter of space and weight, argues a good deal for the type and the practical carrying out of its detail.

Mr. David Rankine makes his filter grids cylindrical and places them horizontally. Those made for the American liners *St. Louis* and *St. Paul*, of 20,000 I. H. P., of the Rankine type, by the Reilly Supply and Repair Company, of New York, had one large " cartridge " to each filter, four such filters being fitted in each ship. These " cartridges " were, however, much too heavy and clumsy for convenient renewal, and Mr. Rankine now makes his filters with a great many small light perforated tubes, very easily handled while

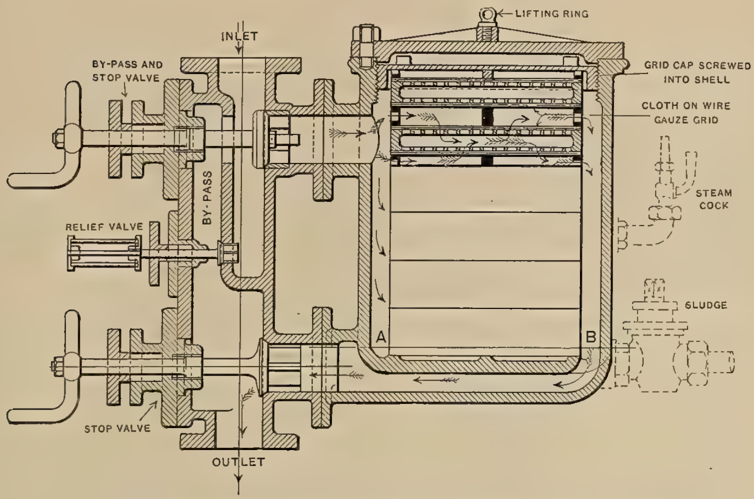


FIG. 7. TORPEDO BOAT DESTROYER FILTER MADE BY THE GLASGOW PATENTS COMPANY, LTD., GLASGOW.

being changed. Fig. 16 shows one of his multiple cartridge designs.

All the filters so far described are arranged for using a filtering medium of linen "Terry cloth," better known as "Turkish towelling." Flannel has also been used. Since, however, it shrinks and rots and cannot be cleaned easily, or used frequently, as linen material can, it is more costly. A silk filter cloth, called "absorbal," for use in these filters is sold by the Glasgow Patents Company, Ltd., and is said to possess, in a high degree, the property of absorbing oily matters.

M. Normand, of Havre, makes a filter which is extensively used in the French Navy. In this he uses sponges alone, arranged in one or more layers, usually three, and generally placed in the hot-well itself or at least between the discharge of the air pumps and the suction of the feed pumps. If placed between the feed pumps and the boiler, it is subjected to considerable variations of pressure which tend to press out the greasy matter already absorbed by the sponges. It is found that when the upper layer is saturated with oil the second has very much less, and the lower layer only a trace, of oil.

The question of easy and speedy renewal of the filtering material has been dealt with in a special manner by Messrs. Alley & McLellan, of Glasgow, whose design is shown in Figs. 17 to 20, on pages 709 and 710.

The filter cover is fitted with a handhole having a door, secured by two bolts only. This hand-hole is placed at the

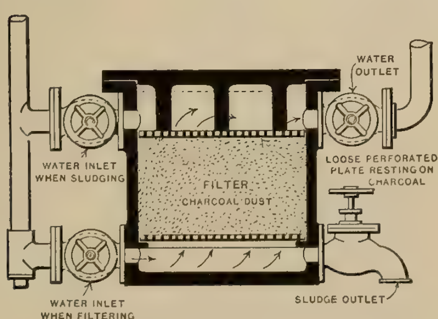


FIG. 8. HARRIS'S ORIGINAL FILTER, 1886.

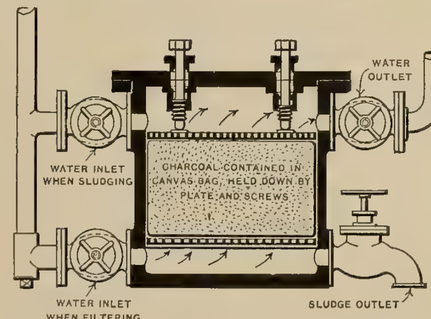


FIG. 9. HARRIS'S FIRST ALTERATION, 1887.

radius of a circle on which are grouped six filtering cylinders, connected by a hollow frame which revolves by applying a spanner to the centre spindle. Thus the whole of the six filter mantles can be successively brought to the hand-hole, withdrawn, new ones put in, and the cover rebolted in about five minutes.

Mr. Alley uses cocoa fibre matting in two thicknesses, with flannel between. These mattings are quite inexpensive and are kept on board as engine room stores, ready to be put in place at any time. The scheme is ingenious and seems to meet the demands of convenience very well.

Another filter in which cocoa fibre is used is Mr. Hockings's, in which loose fibre is packed in an annular space around a cylindrical grid, the water passing radially towards the hollow centre.

This brings us to a scheme more out of the ordinary line, that has been followed in pressure filtration, and though no doubt arrived at from quite independent investigation, the design develops the third stage of Mr. Harris's experiments. This plan is that of Mr. Reeves, of London, shown in Fig. 21. In this filter coarsely granulated pine wood sawdust is used. The apparatus may indeed be described as a bag of sawdust placed in the feed pipe, the bag being made of wire gauze, coarse on the inlet side and very finely mashed on the outlet side.

That sawdust is well adapted for absorbing foreign matters from feed water crucial experiments seem to have shown pretty conclusively. Samples of feed water were drawn from each side of one of these filters fitted at Messrs. Tod's Mills, Leith, Scotland, after it had worked continuously for fourteen days, passing 2000 gallons per hour, no extra pressure due to the filter resistance being observable. Mr. J. T. Norman, of London, made chemical and physical tests of these samples and found that before filtration the water contained 6.5 per cent. of oil and an appreciable quantity (not quantitatively determined) of organic matter and dirt in suspension. After filtration it contained 0.75 per cent. of oil and very little (not estimated) organic matter in suspension.

The process of renewing the sawdust is very simple, occupying from 10 to 25 minutes, according to size. The large blow-out valve at the bottom of the filter is connected to the ship's side, and on being opened the spent sawdust is blown overboard, or, if the sea connection is not approved, a bucket receives the blown-out material. Filling

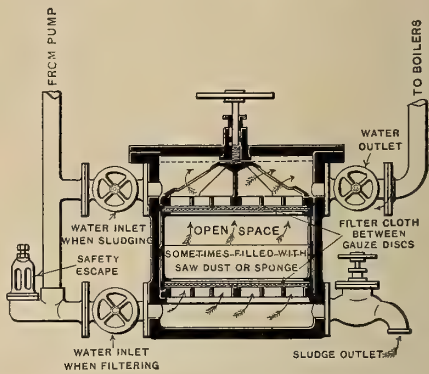


FIG. 10. HARRIS'S SECOND ALTERATION, 1887–88.

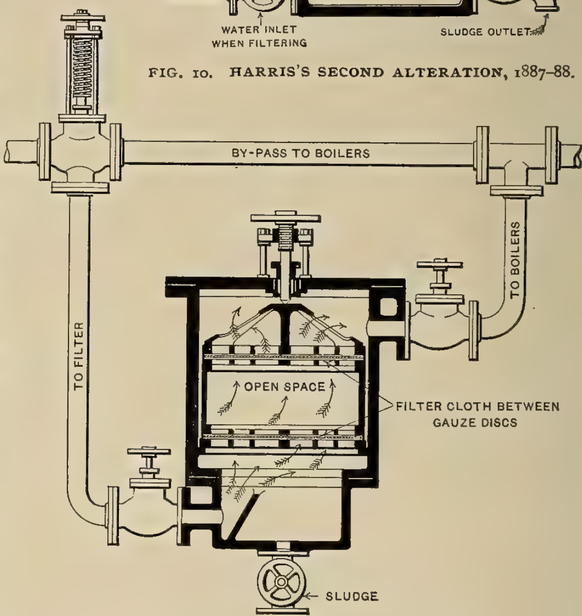


FIG. 11. HARRIS'S THIRD ALTERATION, 1889.

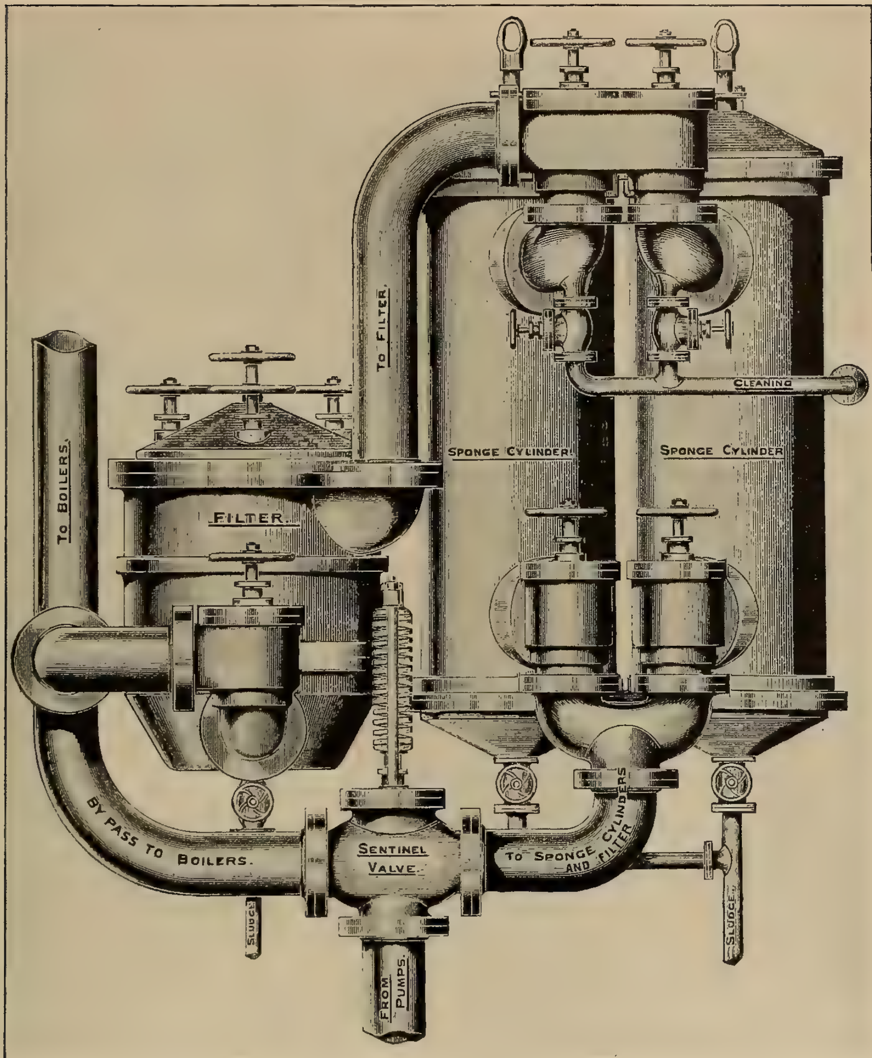


FIG. 12. THE HARRIS COMPOUND FILTER ON THE "LUCANIA" AND "CAMPANIA." MADE BY THE HARRIS FILTER CO., GREENOCK, SCOTLAND.

is done by pouring a "porridge" of sawdust and water through a funnel let into the top plug hole, the water being drawn off, so as to allow the sawdust to settle down into a compact mass in the chamber. As in Messrs. Alley & McLellan's scheme, the removal of a large cover is avoided.

There are many other modifications of this class of grease extractors, depending on "straining" the water, which are more or less used. The grease extractor is sometimes a large chamber in which the grease is allowed to float to the top of the feed water, and is removed by scumming. There are also other kinds of extractors, depending on the interposition in the flow of zig-zag plates, or of a series of shelves, or on centrifugal force within helical walls, and other schemes of a like character for separating out the oily mat-

ters. These, however, do not seem to have got into extensive use.

In working filters, it is found that a clean medium presents a resistance of not over 1 pound per square inch, and while some makers advise the adoption of lower limits, the usual practice is to open up and renew the filtering medium, when it has become so foul as to give a resistance of 25 to 30 pounds in a high-pressure, and 5 pounds in a low-pressure, or suction, filter. The sawdust filter is generally cleaned before such high resistances are reached.

Filter cloths and cocoa mantles are best cleaned, after removal from the filter, by boiling and washing in alkali, but the natural desire of men in charge of engines to delay opening up as long as possible, has induced makers to add steam blowers and soda cocks to their machines, by the aid of which the cloths can be boiled in soda in situ, the dirt loosened being blown off by the sludge cock. Steam is used alone, in some cases, blowing in the reverse direction to the feed and forcing some of the deposit from the cloths.

Experienced engineers are not at all agreed as to the wisdom of either of these practices, alleging, as they do, that the steam blower simply opens up the interstices of the cloths so much as to allow the water to pass through unfiltered, and that the alkali, which should be caustic soda to be effective, destroys the filter and its fittings. Looking to these objections, the Reeves Company claim virtue for the sole use of water in cleaning the chamber.

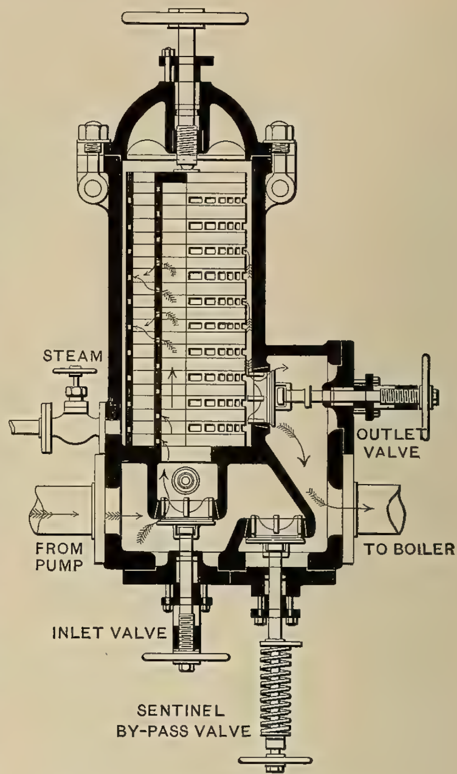


FIG. 13. LATEST MERCHANT SHIP TYPE OF HARRIS FILTER.

The proper way of treating a filter is to take the pains that everything good requires, renewing the cloth as soon as the resistance suitable to its location is reached, and keeping the blower and soda for emergency only. Perhaps the trial trip of a ship may be regarded as a case of emergency for a filter, for then oil is lavished on the engine, inside and out. It is certainly a wise practice, immediately after a trial, to

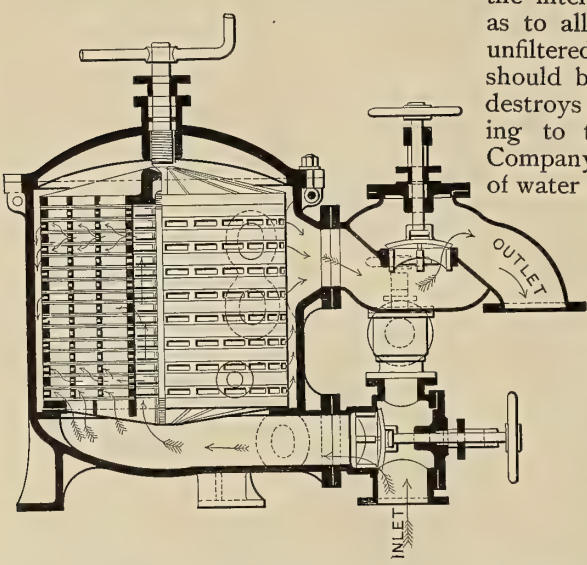


FIG. 14. SECTION OF ONE OF THE TWO HARRIS FILTERS ON H. M. S. "TERRIBLE." EACH EQUAL TO 18,000 H. P.

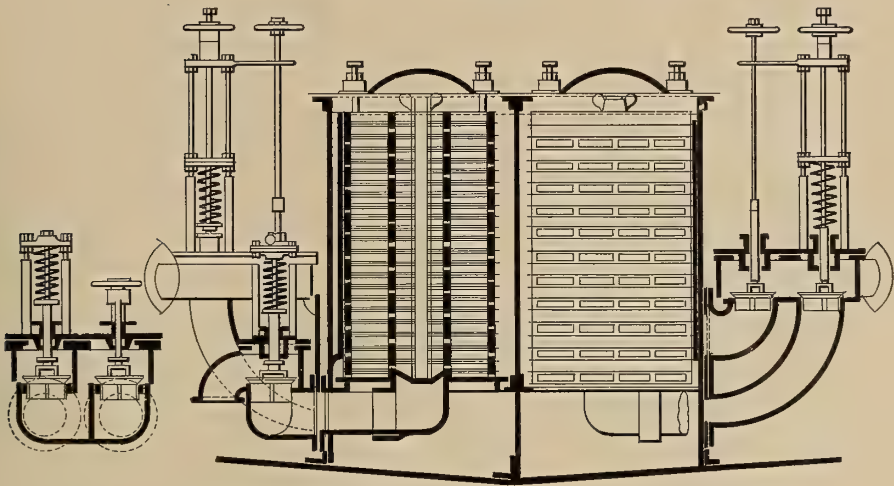


FIG. 15. HARRIS ALUMINIUM FILTER FOR TORPEDO BOAT DESTROYERS.

clean out carefully boilers and pipes as well as filters, so as to be sure of going into normal working conditions free from the germs of disease.

The materials of which filters are constructed vary in the different services, cast iron shells and wrought iron or brass grids being used in the merchant marine service, where weight is not important. Wrought steel shells or brass shells and brass grids are used in ships of the navy. With a view to lightness, Mr. Anthony Harris has experimented with alloys of aluminium, some of which he has found to be about as strong as steel and of only one-third the weight of gun metal. Having tested their endurance in the oily feed water, he is now fitting them on board torpedo boat destroyers, where their lightness is a feature of much importance. It is found that these Harris grid filters, including valves and connections, weigh from 65 pounds to 100 pounds per 1000 I. H. P., according to size, those for 4000 I. H. P. running 100 pounds per 1000 I. H. P., and those for 9000 I. H. P. 65 pounds.

If the oily deposit is arrested because it would damage the boiler when admitted to it, it seems probable that the filter may require to be made of special material to resist the destructive action of its more concentrated and therefore more active contents.

While, generally, filter makers have not experienced appreciable deterioration in their filters, some observant engineers assert that the deposit softens cast iron, eats away the ends of wrought iron or steel grid tubes, and that brass is least sensitive to the corrosive action of greasy deposit and should alone be used for cases and fittings.

To this conclusion it might be objected that a small quantity of cupric compounds from the brass filter might be more dangerous to the boiler than a much larger quantity of iron compounds, that it is better to sacrifice the filter than the boiler, and that, therefore, iron or steel alone should be used.

There are as yet, however, no such serious effects obviously following the choice of material in filters, as to warrant a general and reliable statement other than that where lightness is of more importance than cost, brass or wrought steel, or possibly an aluminium alloy, may be employed rather than cast iron.

In selecting a filter, consideration must be given to the circumstances in which it is to be used. The space at disposal will generally determine the form, and the length of run will determine the size for a given quantity of water. If the run is for one or two days, the filter will be most conveniently made to last without change during the whole run. If the voyage lasts over a long

period, say, thirty days, then space on board might be considered too valuable to devote to a filter large enough to last so long. The size would therefore not be increased, but the filtering material would be frequently blown through or renewed. In this case a design providing means of rapidly renewing the filtering material should be selected. Notwithstanding this, Mr. Harris has, with a view to saving the engine room staff, made a filter to last thirty days without change for a ship trading to the East.

A usual way of speaking of the value of filters is to denominate them by the ratio of area of one stratum of filter cloth to that of the feed pipe, or, in filters containing a medium in mass, by the ratio of the area of the section of the chamber at right angles to the flow, to the area of the feed pipe. Thus, the Glasgow Patents Company's rule is to provide, for filters between the pumps and the feed heater, having three filtrations, 33 times the area of the feed pipe; with two filtrations, 66 times; and with one filtration, 99 times.

Another firm thinks 200 times the area of the feed pipe for one filtration is necessary in filters thus located. On the other hand, the Reeves Company give 3 inches of diameter of chamber for every one-half-inch diameter of feed pipe. This equals 36 times the area of the feed pipe.

It is no doubt convenient for manufacturers to have such rules for classifying goods, but it must not be assumed that the size of the feed pipe is a reliable measure of the work the filter may be called upon to perform, since in practice, the area of the feed pipe does not measure the quantity of water that passes. The velocity of the water in feed pipes varies in different classes of ships from 200 to 1000 feet per minute, and a filter of a given ratio might be required to do five times the work in one ship that it has to do in another.

Again, if I. H. P. is used as a standard of filter area, care must be taken

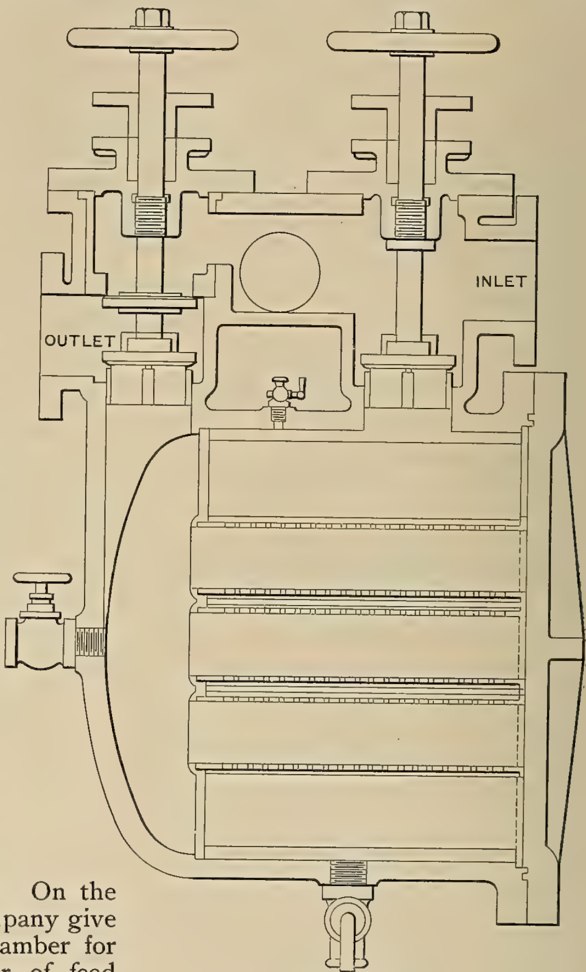


FIG. 16. A MULTIPLE CARTRIDGE RANKINE FILTER.

that I. H. P. expresses, not only the power of the main engines, but also that of the auxiliaries in use at one time at sea, and the water rate per unit of power must be, not that due to the main engines, but that due to the combination of main and auxiliary engines in each case. In some ships,—meat-carrying ships, for instance,—the rate per I. H. P. for the combination of large and

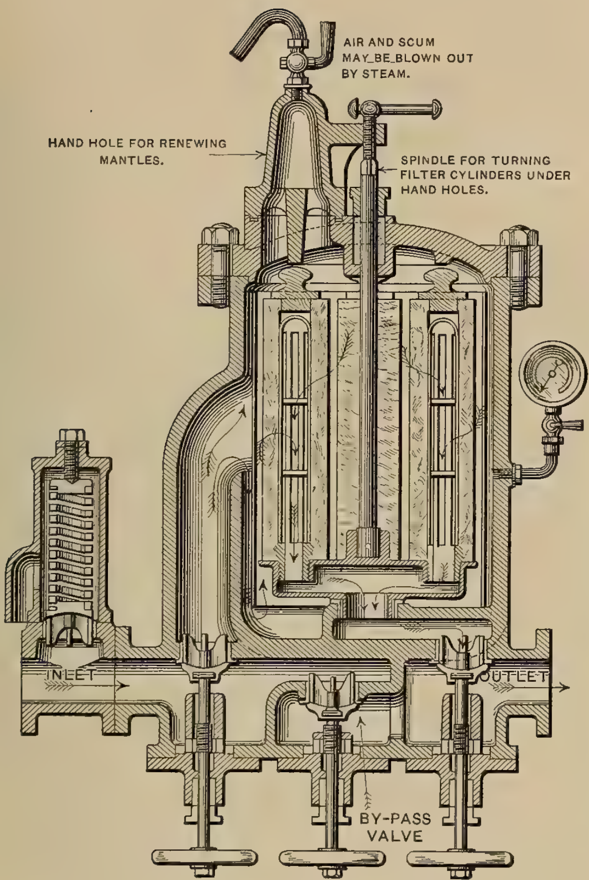


FIG. 17. SECTION OF THE ALLEY & MACLELLAN FILTER.

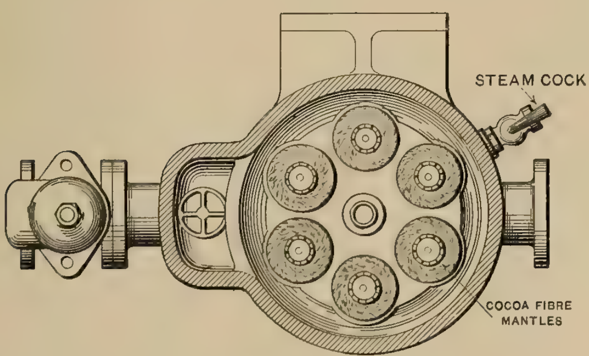


FIG. 18. PLAN, SHOWING THE ARRANGEMENT OF THE FILTER MANTLES.

small engines might be from 17 pounds to 20 pounds, instead of the 13 pounds which might be sufficient for the main engines alone.

The same remarks apply in different degrees to warships and to big Atlantic liners, so that an attempt to use I. H. P. in any general way as a standard or measure of the water used is likely to be delusive. The only rational plan seems to be to estimate carefully in detail the quantity of water requiring to pass to the boilers for all steam engine purposes, and to make the filter area such that this quantity of water passes through its surface at an effective speed.

This effective speed varies with the number of filtrations, with the temperature of the feed water, with the quantity of oil used in contact with steam, with the location of the filter in the feed system, and with what may be called the "working period" or the length of the interval between renewals of the filtering medium.

For filters placed on the discharge to the feed heater and with Turkish towelling as the filtering medium, the Glasgow Patents Company's rule would give, at the very common speed of 400 to 500 feet per minute in the feed pipe,—

For 3 filtrations, 12 to 15 feet per minute through the filter cloths
For 2 filtrations, 6 to 7½ feet per minute through the filter cloths.
For 1 filtration, 4 to 5 feet per minute through the filter cloths.

A feed pipe ratio of 200 would give 2 to 2½ feet per minute through filter cloths.

Mr. Rankine quotes a case as low as 2½ feet per minute, and other designers do not exceed 2 feet per minute in their merchant ship practice,

while in ships with Bellville water-tube boilers and low-pressure filters on the hot-well pump discharges, all the filters being in use, the speed through the filter

FIG. 19. FILTER MANTLES REMOVED FROM FRAME.

surfaces is about 1.5 feet per minute, three successive filtrations being adopted. The Reeves Company's speed would be, at 400 to 500 feet in the pipe, 11 to 14 feet per minute through the filter.

In filters placed on the suction side of the pumps, as very largely adopted in torpedo boat destroyers, light cruisers and yachts, very large surfaces and low speeds are adopted. The Harris Filter Co., Greenock, Scotland, have under construction some filters containing each 100,800 square inches of filter cloth area, equal to 5130 times the area of the feed pipe, requiring a speed of flow through the filter cloth of about one-twentieth of a foot per minute only and involving a resistance, when foul, of only 2 inches of vacuum. When that resistance is reached the sentinel valve opens direct communication with the hot-well.

FIG. 20. FILTER MANTLES IN PLACE.

The proper standardising of filters involves a great deal of intelligent recording and careful analysis of the experiences of many services. This will be got right in time. Meanwhile, filter users should consider it worth their while to consult experienced filter makers, with

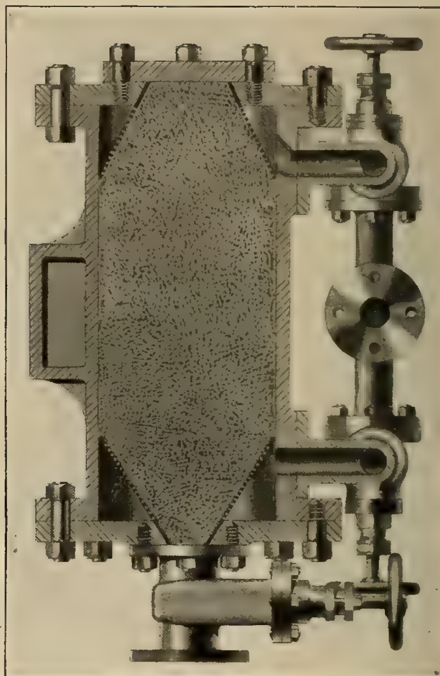


FIG. 21. FILTER MADE BY THE REEVES PATENT FILTERS CO., LTD., LONDON.

a view to determining, first, what are the proportions of a filter effective for the purpose desired; and, second, how not to obtain such a cheap filter that the epitaph of a good boiler gone to ruin in its prime must contain the warning of its history—

"*It was not kept clean.*"

WATER-TIGHT COMPARTMENTS AND BULKHEADS IN STEAM VESSELS.

John H. Morrison.

THE division of the hull of a vessel into compartments is of a more distant period than is generally supposed. As early as the beginning of the nineteenth century the Chinese divided the holds of their trading vessels, intended for distant waters, into a number of smaller holds or spaces. Those compartments were separated by partitions, or bulkheads, made of 3-inch plank, and caulked with a gum that was mixed with lime and threads of bamboo,—a composition that readily hardened when brought into contact with water. The number of compartments depended upon the number of owners in the vessel.

In a large vessel there were sometimes as many as one hundred, each partner shipping his goods in his own berth, which he fitted up to suit himself, and either went in person or sent one of his family to take charge of his property. At just what time this division of the hull was first adopted does not appear to have been recorded. It may have been very old at the period named. The compartments, it will be seen, were made for commercial economy, rather than for the safety of the vessel.

Use of bulkheads for safety purposes was probably first made in the Western rivers of the United States. As early as 1820, not ten years after the introduction of steam navigation on the Mississippi and Ohio rivers by Robert Fulton, the hull of the steamboat *Columbus*, running between New Orleans and Shippingport, Ky., was torn open by a snag, but the vessel was "saved from sinking by having a snag room, which apartment alone was filled with water." The *Caledonia*, running on the Mississippi river in 1824, also had a snag room.

A writer on American engineering previous to 1840 says, regarding this subject:—

"The strongest vessels in the Western waters are unable to withstand the shock occasioned by running against a snag. It almost invariably pierces their bows, when they generally fill with water and go down. Several steamers are built with false bows, called 'snag chambers', as a palliative of the danger arising from accidents of this kind. In event of the bow being stove in, the small compartment, called the snag chamber, in the fore part of the vessel is all that is filled with water, and her buoyancy is thus very little affected."

Prior to the year 1849, of 736 vessels, lost from all causes on the western American rivers, 419 were lost from snags and other obstructions in the rivers. No doubt the danger in navigating these rivers is what brought the snag room or chamber into use, and it was only after the United States Congress had made an appropriation to clear the rivers of snags and other obstructions, about 1828, that there was any comparative safety for western river steamboats. If these snag rooms were as rudely and cheaply constructed as many of these vessels themselves were at this early period, they could hardly be relied on in many cases, and this may account for the fact that they did not come into more general use.

The first use of water-tight bulkheads

in Great Britain was on the iron hull steamer *Garryowen*, built by John Laird, of Birkenhead, for the river Shannon, and first placed in service in November, 1834. There were five compartments in this vessel. The bulkheads were the design of C. W. Williams, who was the managing director of the company to whom the vessel belonged. The same builder, in 1837, sent an iron hull in sections to the United States for the Steamboat Company of Georgia. This was erected at Savannah, Ga., for service on the Savannah river, and had iron bulkheads. The machinery for this vessel was built by Watchman & Bratt, of Baltimore, Md.

In the specification for building a 600-ton wooden hull steam vessel in England in 1839, there is the following item for the bulkheads:—" Solid frames for bulkheads; the frame timbers to be made solid and water-tight, three feet wide (at each iron bulkhead) up the sides to the upper deck; each joint to have felt between; also felt on the out and inner side of the frames before the planks are wrought, so that the vessel may be divided into five water-tight compartments by four iron bulkheads."

The water-tight bulkhead does not seem to have been adopted in the early days of wooden steam vessels, except as represented by the snag rooms on the western American river steamboats; but as soon as iron hull steam vessels were constructed, the water-tight bulkhead (or so named) was brought into service. The United States Naval Commissioners in 1836, when engaged in perfecting a design for the steamer *Fulton*, considered " whether the cavity or interior of the boat can be conveniently divided into several water-tight compartments, so that a leak or injury in any one would not destroy or sink the vessel." But no action was taken toward their use in the building of the vessel.

About the time of the construction of the *Fulton* the United States Congress had under consideration a proposed law for the regulation of steam vessels, and in a report said:—" There is another point respecting the construction of the hull which is of much importance,—making it with wrought iron water-tight bulkheads. This would afford great additional safety, especially on the Western rivers where boats are so often sunk by snags and sawyers. With water-tight bulkheads the sinking of a boat by snagging, it is believed, would be of rare occurrence."

It was thus at an early date that the wisdom was seen of the use of the water-tight bulkhead as a safeguard to a vessel, but it was many years later before it was brought into anything like general use.

While United States government officials were endorsing the bulkhead, American iron shipbuilders, who at that period were marine engine-builders, were making preparations for its use in the vessels of the American merchant marine. A double-hull iron steam vessel, built by the West Point Foundry in New York, for service on Lake Ponchartrain, had two bulkheads in each of the hulls. The latter measured each 110′ × 7′ × 3′6″.

In 1840 the iron steamboat *Valley Forge* was built at Pittsburgh, Pa., for the Ohio and Mississippi river trade. She measured 180′ × 25′ × 5′6″, and had several water-tight compartments, secured by longitudinal and athwartship bulkheads, but notwithstanding these safeguards she was sunk in the Mississippi river in 1842 or '43. The iron hull steamboat *John Stevens*, built in 1845 for the Delaware river, had an iron water-tight collision bulkhead 27 feet from the stem. This vessel has been for many years in New York harbour as a cattle transfer boat. The wooden steamer *San Francisco*, built in 1853, had the engine space enclosed in two cross-planked and iron braced bulkheads that extended to the spar deck. This vessel was lost on her first voyage, in December, 1853, in a gale off the coast of North Carolina.

The occasion that was the means of giving greater safety to steam vessels, especially sea-going vessels, than had heretofore prevailed in the United States was the loss of the steamer *Arctic* of the Collins line, on September 27, 1854,

when about 300 lives were lost. While there were a few wooden-hull steamers that had a bulkhead, or probably two, dividing off the engine and boiler spaces from the cargo hold, there was little pretence to making such bulkheads water-tight.

It was early found that a wooden bulkhead could not be relied upon because of the shrinkage of the wood, caused by the heated air in the hold of the vessel, coming from the engine, boiler and auxiliaries, and the working of the frame of the vessel in a seaway. With these disadvantages, in a few years after the loss of the *Arctic* every new sea-going steamer had a collision bulkhead at least, and in many cases the hold also was divided into three or more compartments.

Charles Maliphant took out a patent in 1858, and assigned it to Thomas West, of New York, for an improved bulkhead, consisting of double diagonal planking, with felt between the planking, and stanchions on either side of the planking. Pacific mail steamers were fitted with these bulkheads, the first being the *Constitution*, in 1861, and also some of the Long Island Sound steamers.

Iron bulkheads were also tried in wooden hulls; but the elasticity of the wooden frame and the rigidity of the iron bulkhead soon loosened the fastenings between the two, and left the latter useless.

Several steamers of the United States Navy had water-tight bulkheads. The *Michigan* (iron), built in 1843, had one forward and one aft of the engine room. There were several of wooden-hull United States steamers previous to 1860 that were fitted with these bulkheads,—the *Powhattan*, *Susquehanna*, *Brooklyn*, *Lancaster*, and probably one or two others.

There would seem to be no doubt that the *Ellen S. Terry*, iron hull and screw propeller, built in 1857 by the Harlan & Hollingsworth Company, at Wilmington, Del., for a coastwise trade, was the first vessel built in the United States having five water-tight compartments. The same builders had constructed four vessels previous to this, each having four compartments; and in 1858 they built, among others, the steamer *Champion*, having four compartments, for Commodore Vanderbilt.

There is indisputable evidence that there were some collision bulkheads in wooden-hull vessels that were of service when most needed. The *Montreal*, running between Boston and Portland, was run into on the night of August 10, 1858, by the *Lewiston* and cut down to the water's edge, and the steamboat inspectors' report says that the vessel was "saved from foundering immediately after the collision only by a water-tight bulkhead with which she was provided (and with which all steamers belonging to the same company are fitted) a few feet aft from the stem . . . and she returned to Boston, a distance of about fifty miles, with both passengers and freight uninjured."

The steamboat *Empire State*, of the Fall River Line, was run into by the propeller *Franconia* on the night of February 6, 1865, "striking her about 20 feet aft of the stem, and was saved from sinking only by having a well-constructed water-tight bulkhead a few feet aft of the fracture."

On the Sacramento river, California, there were, prior to 1855, two or three vessels of about 150 tons each that had their holds divided into compartments, as a precautionary measure against the snags liable to be encountered on the river. In 1858 there were on the same river nearly twenty vessels, both side and stern-wheelers, that were so fitted.

There are several steamboats on western American rivers at this day that have their holds divided into spaces, principally for the purpose of giving additional strength to the hulls. In the iron hulls they are water-tight. Several of the Union gunboats on these rivers during the American Rebellion had water-tight compartments. The United States lighthouse steamer *Joseph Henry*, built in 1879, has three fore-and-aft bulkheads, and five athwartships. Her duty is on the Mississippi river.

There were steamboats on the Columbia river and Snake river, in Oregon,

previous to 1860 that were built with compartments. These boats were stern-wheelers and about 150 feet long. The hulls of the vessels were divided by fore-and-aft and athwartship bulkheads, no freight being carried in the holds. Each compartment was supplied with a hand pump, and in some instances with a steam pump, having pipes leading into the principal compartments.

The boats of the Oregon Railroad and Navigation Company of the present day have from 4 to 10 feet depth of hold and three or five keelsons. The fore-and-aft bulkheads are placed on top of the keelsons and reach to the deck beams. They are edge-bolted through the bulkhead with ⅞-inch iron, with a nut on top and underneath the keelson, the bolts being about 4 feet apart. The transverse bulkheads are built of 1½″ to 2″ planking, reaching to the full depth of the hold, and are caulked with heavy canvas that is painted and placed all around the edges of the bulkheads against the frame and outside planking. The limber holes are cut out of the bottom of the frame, and at each bulkhead is hung a plug ready for use. Each compartment is provided with a hatch from the freight deck, and in the event of necessity the bulkheads can be made water-tight almost instantly.

In a boat 150 feet long and 32 feet beam there are about 32 compartments. A short time ago one of these vessels had a hole torn in her bottom carrying away frames and transverse bulkheads for 30 feet, and about 5 feet wide on the floor, all timber being destroyed. The vessel was one hundred miles from her port, yet she brought in her passengers and cargo only one hour behind her schedule time.

There has been no more noteworthy example of the value of water-tight bulkheads, when properly designed, than the accident which occurred to the American Line steamer *Paris* in March, 1890. When about 200 miles off the Irish coast, the shaft of the starboard engine broke, wrecking the whole structure. Besides the starboard engine room compartment, the port engine room space was filled with water through two ruptures made in the bulkhead separating the engine rooms, as well as two other compartments aft of these spaces. There were sixteen compartments in all in the vessel, all the bulkheads running to the saloon deck without any opening as means of communication, except a door in the bulkhead between the engine room spaces. The flooding of the starboard engine room was caused by the wrecking of the condenser, and the water pouring in through the broken pipes and open valve. After the accident the vessel drifted about the ocean for nearly two days, and was later towed to Queenstown.

CARBURETTED WATER GAS.

By Arthur G. Glasgow.

A Partial Reprint of a paper originally presented to the Cleveland Institution of Engineers in January, 1897. The illustrations have been specially prepared for publication in this magazine.—THE EDITOR.

WATER gas derives its name from the fact that three-fifths of its weight and three-quarters of its bulk consist of the oxygen and hydrogen obtained by the decomposition of steam. Steam cannot be decomposed by the direct action of heat alone; but when subjected to a high temperature in the presence of certain "reducers"—that is to say, certain substances which at such high temperature have stronger affinity for the oxygen of the steam than has the hydrogen with which it is combined—the oxygen will combine with this "reducing" element, and set the hydrogen free. In the manufacture of water gas, the well-known affinity of heated carbon (coal or coke) for oxygen is utilised in thus resolving steam, the hydrogen being liberated, and the oxygen combining with the carbon to form carbonic oxide.

The chemical reactions, according to which this decomposition takes place, may be written thus—

$$\underset{\text{Water.}}{2\,H_2O} + \underset{\text{Carbon.}}{C} = \underset{\text{Hydrogen.}}{2\,H_2} + \underset{\text{Carbonic Acid.}}{CO_2}$$

In the presence of an excess of carbon, however, the carbonic acid saturates itself by taking up another carbon atom, thus—

$$\underset{\text{Carbonic Acid.}}{CO_2} + \underset{\text{Carbon.}}{C} = \underset{\text{Carbonic Oxide.}}{2\,CO}$$

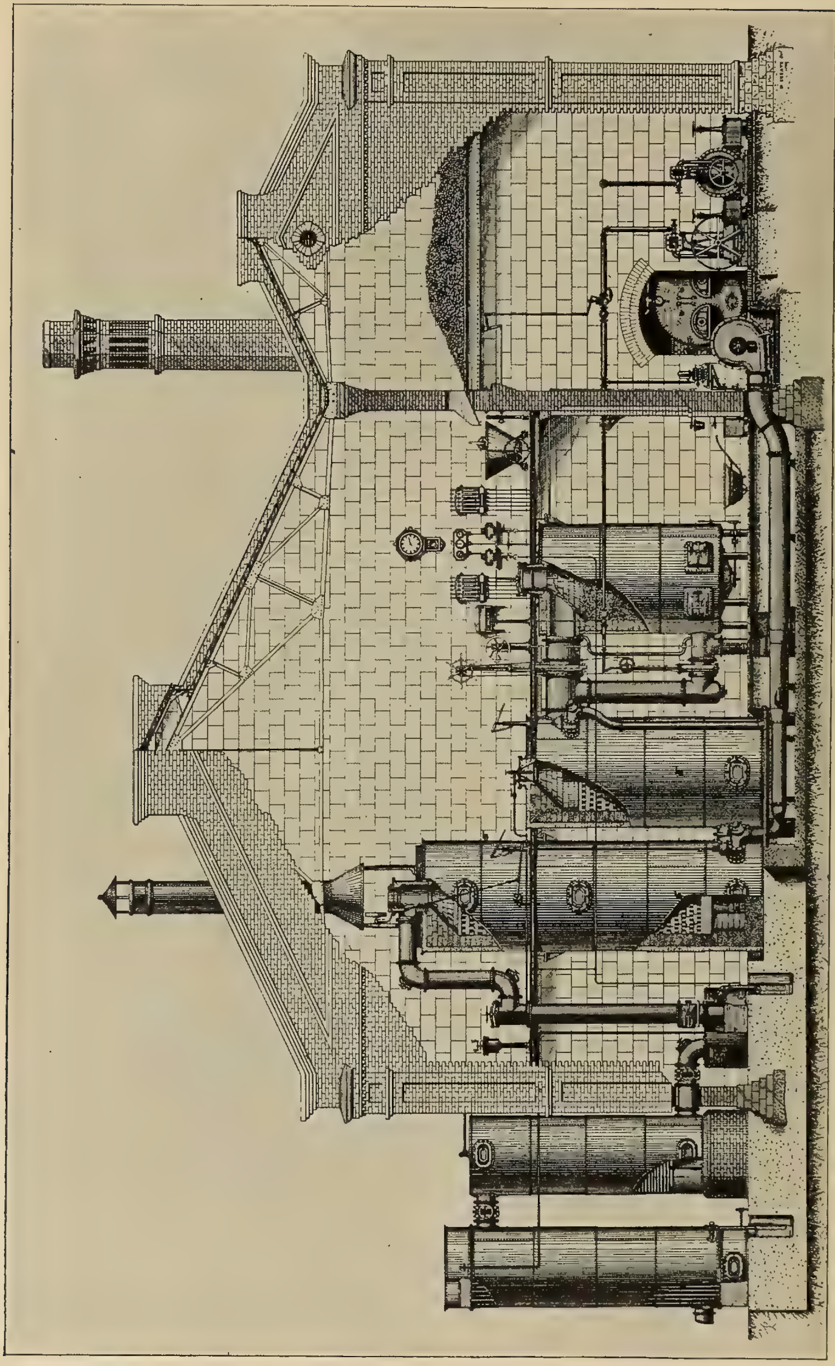
making the finished product

$$2\,H_2 + 2\,CO$$

This finished product (hydrogen and carbonic oxide in equal volumes) is practically odourless and non-luminous, burning with an intensely hot flame. It may be called "theoretical" water gas, for in practical working the reduction of carbonic acid (CO_2) to carbonic oxide (CO) is never quite perfect, the unpurified gas usually containing about 3 per cent. of the unreduced acid, to be extracted (as in the case of coal gas) by lime purification.

In the process to be presently described, water gas is generated by passing a current of steam through a deep bed of incandescent coke, and as it issues from the generator into the adjoining carburetter, this hot gas is enriched to any desired point, by means of crude oil or cheaper distillates. Hence the name carburetted water gas, the hydrocarbons thus derived from the oil imparting to the gas an odour as pungent and characteristic as that of coal gas.

It is manifest that, unless we in some way replenish the heat as it is extracted from the generator, the fire will be gradually extinguished and the generation of gas cease. There are two ways of supplying this lost heat:—First, by external combustion—that is, by independent firing beneath or around the vessel containing the decomposing fuel-bed. Of this method, which at one time received much attention, there are no examples now extant. Secondly, by intermittent internal combustion, as in the process about to be described; the "runs" (or periods of gas making) and "blows" (or period of air-blasting)—when the production of gas is intermitted in order to recuperate the temperatures within the apparatus—succeeding each other at regular intervals. Now when we admit air to the bottom



A MODERN CARBURETTED WATER GAS PLANT.

of a heated fuel-bed of considerable depth, it is a "producer" gas—not the product of finished combustion—that escapes from the top, the energy of this gas varying inversely with the power of the blast and directly with the temperature and depth of the fuel-bed; and the distinguishing economic feature of the process under discussion consists in utilising the energy of these blast gases issuing from the generator during the "blow" for subsequently gasifying the enriching oil in the presence of the hot water gas concurrently produced.

The following description will be made clear by reference to the illustration on the opposite page, showing the apparatus in its usual sequence, viz., generator, carburetter, superheater, oil-heater, washer or seal, scrubber, and condenser, the last two being shown outside the building.

The generator, carburetter and superheater are cylindrical steel shells, thickly lined with special fire-blocks, between which and the metal are annular spaces packed with non-conducting material, reducing the radiation to such a minimum that the hand may be held upon the metal casings. The generator is usually supported on short columns, leaving cartage room under the hopper-shaped ashpit. The grate, controlled by the several cleaning-doors, is located slightly above the ashpit; and the fire is charged with coke through the door in the extreme top. The generator is connected, both above and below the fuel-bed, with the top of the carburetter, the bottom of which leads laterally into the adjoining superheater. The carburetter and superheater—often referred to as the "fixing chambers"—are filled with checker-work, designed and spaced as

A CARBURETTED WATER GAS PLANT AS DESIGNED BY MESSRS. HUMPHREYS & GLASGOW, LONDON AND NEW YORK.

determined by long experience, and affording such an enormous heating surface that the most difficult and persistent vapours may be permanently gasified at the lower temperatures necessary for the highest illuminating effect. At the top of the superheater is a valve-controlled outlet for the blast products. During the " run," or period of gas making, this outlet is closed; and the carburetted gas escapes through the side take-off pipe into the small vertical casing of the oil-heater, and thence, forcing the seal in the washer, through the scrubber and condenser to the relief-holder.

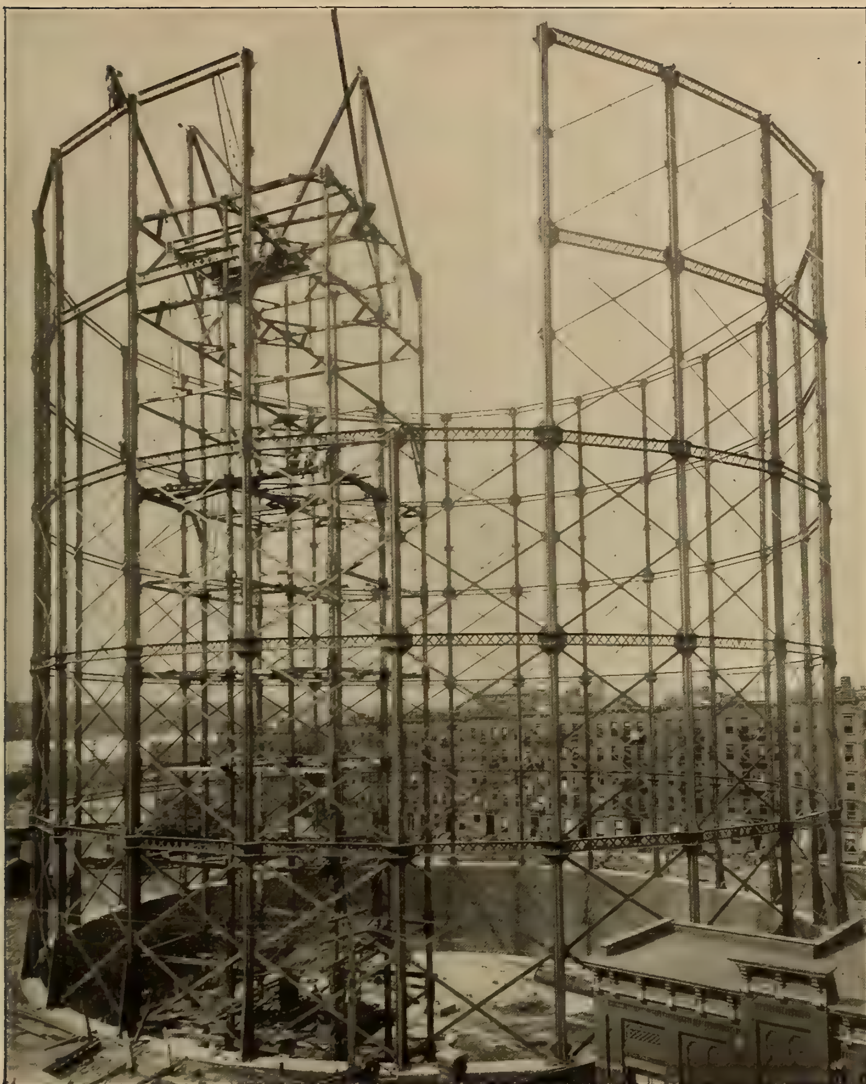
The oil-heater is a simple and practical arrangement for pre-heating the oil on its way to the carburetter by means of the hot gas escaping from the superheater; and a steam-pump connected with the storage-tank delivers oil at a constant and moderate pressure through a meter and this heater, to a centrifugal distributor in the top of the carburetter. Thus the heated enriching oil is introduced at right angles to the cross section of the carburetter, in an atomised spray that uniformly covers the sectional area; and there is no way for the light vapours—frequently the most difficult to permanently gasify—to short-circuit the route, the whole necessarily traversing the great combined length of both carburetter and superheater.

WATER GAS PLANT AT GLASGOW.

This is particularly worth noting, since it was the confusion of the principle of fractional distillation with that of permanent gasification, that chiefly retarded the perfection of carburetted water-gas apparatus; and to this day, there is something in the idea of fractional distillation that fascinates most immature designers. Of the many "improved" types of apparatus promoted during the past several years, I do not recall one that has not offered as its distinctive advantage the fractional treatment of the oil, generally by introducing it at an intermediate point in the height of the superheater, enabling the lighter vapours to quickly escape from the top, while the heavier unvapourised portion was supposed to fall back against the current of the water gas, thus traversing the entire height of the chamber.

It may be taken as the first requisite of the economical gasification of oil that it shall be exposed to a large surface at a uniformly low temperature. Furthermore, this surface should consist of length in the direction the gas travels, rather than cross section, as the oil vapours should never be allowed to approach a condition of rest in contact with the heated surface in the fixing chambers.

An elevated operating-floor, flush with the generator charging-door, affords the best means of manipulating the plant; consequently all levers, valves, and appurtenances requiring at-

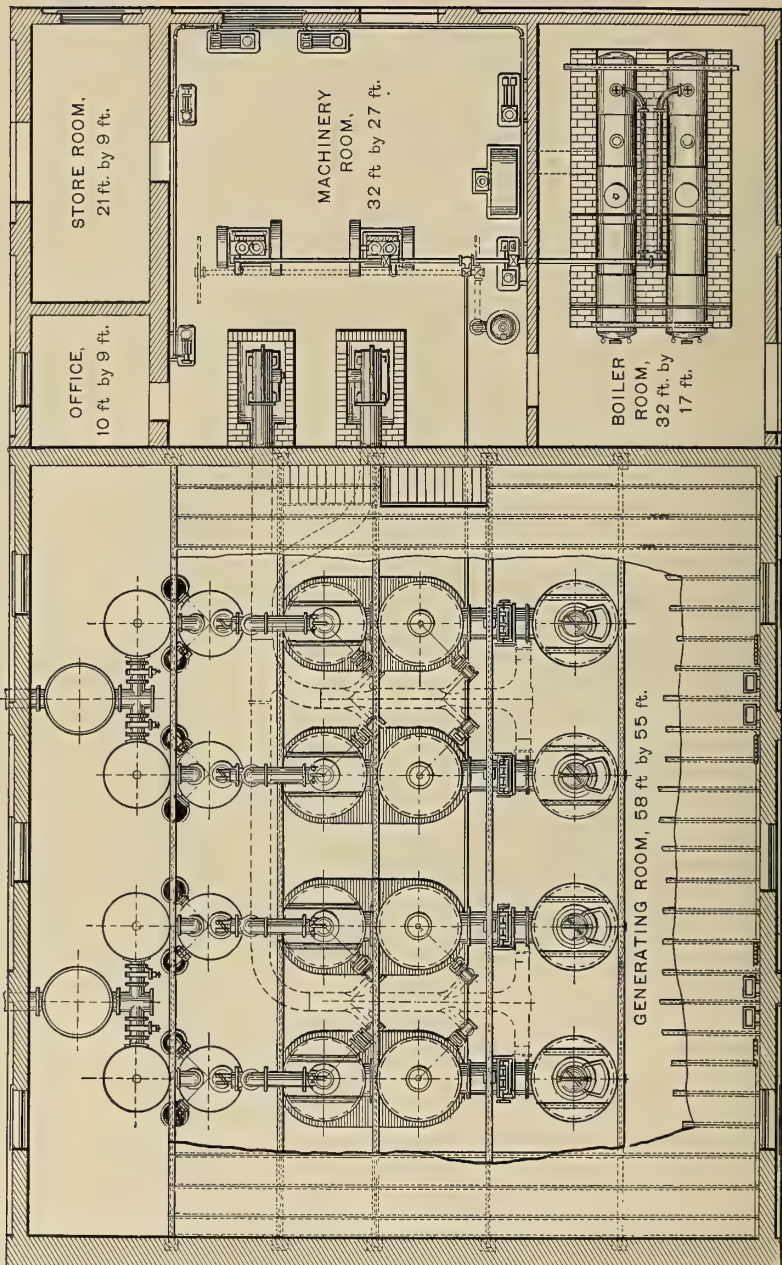


BY COURTESY OF MESSRS. MILLIKEN BROS., NEW YORK.

A MODERN GAS HOLDER FRAME.

tention are assembled at this level. It is here that the gas maker is stationed. The air-ducts, situated below the ground-floor, and leading from the blower to the generator, carburetter, and superheater, respectively, are controlled by valves regulated from the operating-floor. The battery-gauge, indicating the pressure at the various stages of the process, apprises the gas maker of the working conditions throughout the apparatus. An interlocking valve gear precludes the movement of valves except in their safe and proper sequence.

The method of operating is the following:—A fire is started in the generator, which is then deeply charged with coke and opened to the blast. The air enters in large volume below the grate, and quickly kindles the fuel. The hot products resulting from partial combus-



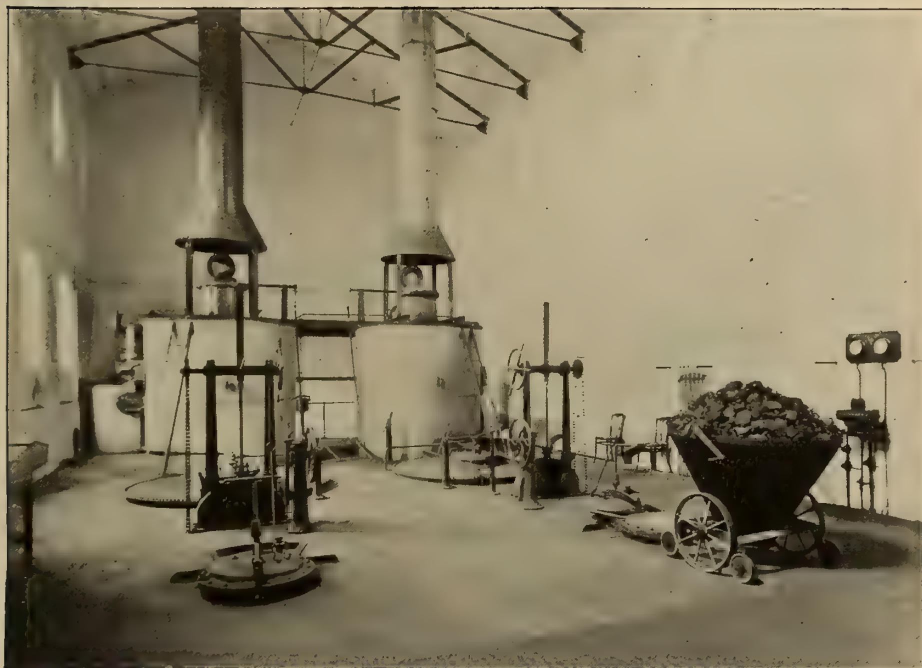
GROUND PLAN OF THE GAS WORKS AT TOTTENHAM, ENGLAND.

tion pass forward through the carburetter and superheater, and after parting with their sensible heat, escape into the stack. As soon as the generator gases have sufficiently warmed the checker-work, supplies of secondary air are admitted to the top of the carburetter and the bottom of the superheater, respectively, and the combustion is regulated to give the requisite temperatures in the three vessels simultaneously.

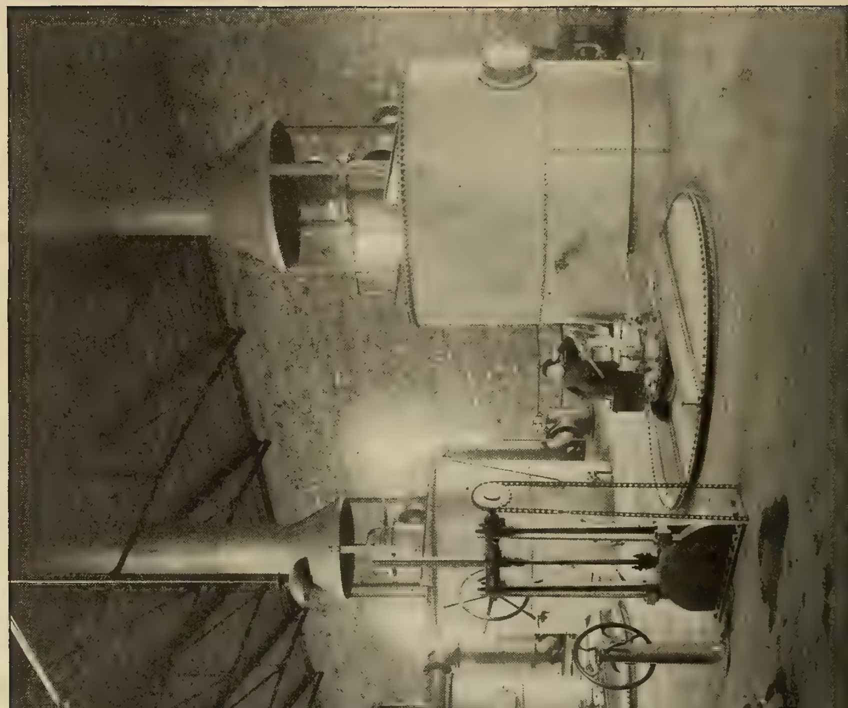
The generator fire being in proper condition, and the carburetter and superheater at the desired temperatures, the apparatus is ready for gas making. The blasts are shut off one by one, beginning with that of the superheater; the stack-valve is closed; and steam is admitted under (or over) the fuel-bed, and, having traversed it, passes as water gas into the top of the carburetter. At this point the oil is introduced as already described, and, encountering the heated checker-work, it is vaporised and ultimately gasified in the beneficial presence of the hot water gas.

This process continues without intermission until the temperatures of the fire and checker-work are sufficiently reduced. The oil is then shut off, and next the steam; the stack-valve being opened, the blasts are again admitted, and the energy of the fire and the checker-work recuperated as first described.

The generator has to be supplied with fuel at intervals of from 45 to 60 minutes, and cleaned usually once during each shift. With intermissions of firing and cleaning, the process consists solely of the operations described, alternating at regular intervals, as observed by the clock, and it is so simple in practice that its routine may be efficiently acquired by an ordinary workman in a few days. The gas passes from the seal through the scrubbers and condensers, and is subsequently deprived of its carbonic



THE OPERATING FLOOR OF THE BELFAST WATER GAS PLANT. EQUIPPED BY MESSRS, HUMPHREYS & GLASGOW, LONDON AND NEW YORK.



THE GAS PLANT AT LIVERPOOL.

Properties of Carburetted Water Gas.

	Double Superheated Apparatus in 1895.		Water Gas in 1885.		Heidelburg Coal Gas.
Carbonic Acid, CO_2	2.20	0.60	0.14	0.30	3.01
Oxygen, O	----	0.40	0.06	0.01	0.65
Ethylene, C_2H_4	2.80	8.00	11.29	12.80	2.55
Propylene, C_3H_6	8.00	6.00	----	----	1.21
Benzole, C_6H_6	2.00	2.00	1.53	2.63	1.33
Carbonic Oxide, CO	24.20	23.00	28.26	23.58	8.88
Marsh Gas, CH_4	17.83	20.80	18.88	20.95	34.02
Hydrogen, H	37.95	34.00	37.20	35.88	46.20
Nitrogen, N	5.02	5.20	2.64	3.85	2.15
	100.00	100.00	100.00	100.00	100.00
Approximate candle power	28	30	22	26	14
Specific gravity (calculated)	.6425	.6483	.5825	.6057	.4580
Flame Temperature	5275.6° F.	5190° F.	5311° F.	5281° F.	5203° F.
Heat-units* per cubic foot of gas—					
Calculated	704.70	735.90	650.00	689.00	642.00
Observed	708.90	736.70	----	----	----
Cubic feet of air required for perfect combustion—					
Per cubic foot of gas	6.12	6.50	5.52	6.20	5.63
Per pound of sperm	63.70	63.20	73.20	69 60	117.30
Cubic feet of resultant products, including aqueous vapour—					
Per cubic foot of gas	6.92	7.60	6.20	6.90	6.37
Per pound of sperm	72.10	73.90	82.20	77.50	132.70

* For equal candle powers, the heating effect of carburetted water gas is somewhat (about 5 per cent.) less than that of coal gas.

acid and treated for its slight sulphur impurities in the manner common to coal gas.

A feature of note in the process, is the reversing or " alternative " method of gas production in the generator. If steam be always admitted to the bottom of the fuel-bed, the heavy duty of its decomposition is too largely performed by the lower portion of the fire, which becomes, in time, inactive and deadened beyond the point of ignition. The succeeding air-blast, therefore, instead of rekindling it, chills this lower stratum almost to the temperature of the outside atmosphere; and when steam is again admitted, it condenses freely in the cold cinder. Frequent removal of this condensing stratum is both laborious and wasteful. Periodically reversing the current of steam in the generator, comprehensively corrects the above evil by distributing the duty of the fuel-bed throughout its entire bulk. As this reversal is completely effected in one movement, possibility of confusion or mistake is precluded.

The chemical and physical properties of carburetted water gas may be illustrated in the table on this page, based upon determinations by Messrs. Shepard, Bruckner and Schimmel, and Dr. Gideon Moore.

There are two features of the highest importance that are not exemplified in this table, the first being the character of the flame. Taking carburetted water gas and coal gas of equal candle powers, the former burns with a smaller and much more brilliant flame, the intense incandescence to which the carbon particles are exposed leading to greatly improved combustion. This feature is farther reaching in its effect than may be at first supposed, for the great objection to lighting by gas, which is the ruling consideration in almost every instance of its displacement by electric light, is the inevitable destruction of ceiling and other decorations owing to imperfect combustion at the burner and the generation of noxious sulphur products. The writer speaks from absolute as well as common experience when saying that the 30-candle power carburetted water gas of New York and other American cities is used, in ordinary flat-frame burners, with a freedom from soot and noxious products unapproached in towns supplied with ordinary coal gas.

This striking advantage is now conceded to be due to the greater percentage of carbonic oxide in the former gas, which, to use Dr. Moore's words, by " its density and high flame temperature greatly promotes the illuminating effect and retards waste." The increased proportion of this same gas, be it noted,

was once decried as a menace to health and life.

An important fact, not shown in the table, is that carburetted water gas contains scarcely one-fifth of the sulphur usually present in coal gas; and this being almost exclusively in the form of sulphuretted hydrogen, oxide of iron purification alone reduces the sulphur below 5 grains per 100 cubic feet.

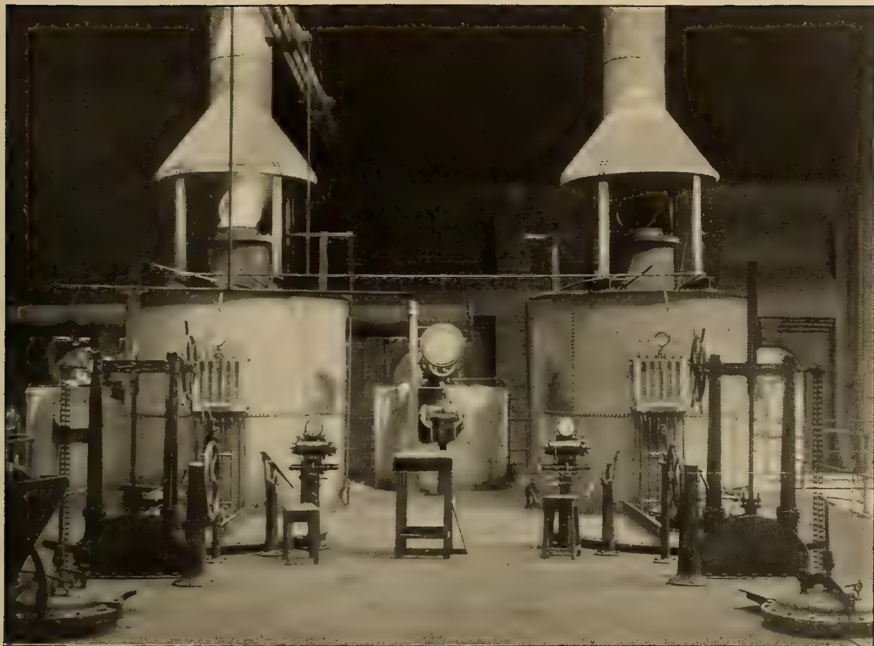
There is yet another physical property of carburetted water gas that is worth bearing in mind. It is that, when mixed with coal gas, it acts as a solvent vehicle for naphthalene, and, except in rare instances, prevents its precipitation from the latter gas.

The auxiliary manufacture of carburetted water gas affords a perfect, and the only known, means of combining production with enrichment in proportions that may be instantly adjusted to suit immediate requirements. If, owing to intense frost, variation in the character of coal, or other cause, the quality of the coal gas cannot be maintained, a change in the valve controlling the oil supplied to the carburetter instantly compensates for the deficiency. Nothing else is necessary, and no routine is altered. If, on the other hand, a sudden demand arises for more gas, a reserve section is in full operation within three hours, and a change in the oil valve now reduces the quality in correspondence with the increased bulk. The quantity and quality of the commercial gas leaving the works is thus absolutely maintained without interference with the normal operation of the coal-gas benches. This naturally results in decreased working expenses and retort-house repairs.

But the most convincing reason why carburetted water gas is at its best when one of its functions is the enrichment of lean coal gas is that the higher its quality, within practical limits, the cheaper is its cost per candle. Suppose, for instance, that we are making carburetted water gas of 18-candle power at 1s. per 1000 cubic feet with 2½ gallons of oil costing 3d. per gallon, then by simply an additional gallon of oil, or 25 per cent. of the total cost, the quality of the gas is raised to 25 candles, or 40 per cent.; and the original 1000 cubic feet are increased to about 1100 feet by the bulk derived from the extra gallon of oil. Hence you will be prepared for the statement that in many localities enrichment by carburetted water gas costs *nil*, since the enriching gas, though of higher candle-power, costs less per 1000 cubic feet than the lean coal gas. This contrasts strikingly with the waning method of enriching coal gas by means of cannel, whereby the cost of each candle of enrichment above the normal quality yielded by the coal, frequently reaches 2d. per 1000 cubic feet. Such a practice has inevitably resulted in a disposition among many gas manufacturers to consider the present standards of illuminating quality onerous.

Whether or not carburetted water gas is more economical than coal gas, must be determined by individual comparison —it is a question of locality rather than process. As an auxiliary to coal gas manufacture, however, there can be no doubt of its universal applicability throughout the United Kingdom, and as a forceful example, I may describe the general situation at Belfast.

Before the installation of carburetted water-gas plant, the cost of manufacturing coal gas was 13.35d. per 1000 cubic feet, and the greatest year's profit ever yielded by the undertaking was £23,000. During the first year, making but 20 per cent. of carburetted water gas, the profit rose to £34,000, though according to the general books, the new gas cost 13.324d. per 1000 feet, showing no appreciable saving. This anomaly is easily explained, in view of what we have learned as to the "collateral" advantages of carburetted water gas—especially when used as an enricher. In the first place, the immediate result of the starting of the process was the abolition of cannel enrichment. This, while relieving the coal gas of an expensive burden, added somewhat to the cost of water gas by necessitating an average of 24-candle power for the year. In the next place, as soon as the decreased production of coke had enabled the large accumulations to be dis-



THE OPERATING FLOOR OF THE PLANT AT BRIGHTON, ENGLAND.

posed of, its price was advanced 2s. 6d. per ton, the whole of the revenue going to the credit of coal gas; whereas the water gas—if required to pay this enhanced price—would, of course, be injuriously affected in the accounts. Thirdly, no retorts were fired except those kept in continuous working throughout the season, the water-gas plant being utilised to meet all fluctuations in output as well as the heavy mid-winter consumption. Thus coal gas again benefited by a material saving in fuel, labour, and retort-house repairs, at the expense of the intermittent working of the water-gas plant.

Of the second year, recently ended, I have no information,* other than that the net profit exceeded £55,000; resulting in a reduction of 3d. per 1000 cubic feet in the price of gas.

Roughly speaking, therefore, it appears that the manufacture of carburetted water gas has doubled the profits of the Belfast undertaking, though an analysis of the general accounts shows the present cost of coal gas, per 1000 cubic feet, to be far less than that of water gas. In other words, the enormous saving has been in the reflex action of carburetted water gas upon coal gas manufacture.

The appended liberal estimate serves to illustrate the various items that enter into the cost of manufacturing carburetted water gas of 24-candle power:—

Oil, 3½ gallons at 3d	10.500d.
Coke (including boiler fuel), 40 lbs., at 12s. per ton	2.500
Labour, total employed	1.500
Purifying materials	0.500
Repairs and maintenance	0.500
Water (if not recirculated)	0.200
Management and sundries	0.300
	16.000d.
Less value of oil tar recovered	0.500
Total cost per 1000 cubic feet made	15.500d.
Plus 5 per cent. loss in distribution	0 780
Total cost per 1000 cubic feet sold	16.280d.
Cost per pound of sperm sold	0.198

It will be noted that this estimated figure of total cost is 3½d. higher than the actual cost of gas of practically the same quality during the past year at Belfast.

The following figures, averaged from "Field's Analysis" for the six years

* I have since learned that the cost of the carburetted water gas was reduced to 12.05d. per 1000 cubic feet.

1890-95, give the manufacturing costs of the London and of the Suburban Companies per 1000 cubic feet of coal gas, with the sperm equivalents:—

	Candle Power.	Cost per 1,000 Cub. Ft.	Cost per Pound of Sperm.
London	16	15.49d.	0.274d.
Suburban	15	18.25	0.342

Much has been written encouraging the popular misconception — inaugurated by the misleading tendency of the name itself—that the process derives some thermal benefit from the use of water, notwithstanding the fact that water is a product of finished combustion, being the saturated staple compound of hydrogen and oxygen. Whenever and wherever this combination is effected, 61,500 units of heat are evolved per pound of hydrogen, and the resultant product can be decomposed only by the absorption of an exact thermal equivalent. Further, the combustion of the hydrogen present in water gas (uncarburetted) yields precisely the quantity of aqueous vapour originally decomposed in the production of the gas; and, assuming this water to enter and leave the system at the same temperature, its thermal influence must be *nil*. In other words, we can neither create nor destroy energy or matter.

Looking behind the scenes, therefore, we find that water is merely a transporting agent, providing a means by which the energy of solid carbon can be distributed in gaseous form, and that it is in reality the carbon consumed in the fuel-bed that is the true source of all the heat developed. A continuation of this argument will show the worthlessness of schemes for making the generating process continuous, by superheating the steam before its admission to the fuel-bed. Even when superheated to 1500° F., the steam carries scarcely 9000 additional heat units, or but 2½ per cent. of the energy absorbed in the manufacture of the carburetted product.

BRAKES FOR HIGH-SPEED RAILWAY TRAINS.

By Louis H. Walter, Assoc. Mem. I. E. E.

A GOOD deal has been written during the last few years on the subject of high speed railways and travelling, but few practical experiments have been made on any large scale. Those trials, however, which have been carried out indicate that there is no exceptional and inherent difficulty in the way of high speeds, while one dreaded factor, the air resistance, has been proved to have a much smaller value than that which was, until recently, accepted.

With electricity as the motive power, properly designed trains, or cars, could certainly be run up to 120 or 150 miles an hour, and advance in this direction depends almost entirely upon the character of the track, though nothing beyond a fractional increase in speed seems obtainable from ordinary steam locomotives. It is a fact that very few accidents do occur which can be directly attributed to high speeds on ordinary railways, having regard to the number of fast expresses run daily both in Europe and in the United States. Although on these lines the speed rarely exceeds 70 miles an hour on the most favourable parts of the track, this is high, considering the shape of the vehicles and the

number of points and crossings passed over on an average run.

A considerable amount of thought appears to have been devoted to the question of retarding appliances suitable for speeds of 100 miles an hour and over. It appears to the writer, however, that the full significance of the limitations to speed, due to considerations of safety, which the small braking force obtainable by any means at present used imposes, is not grasped as it should be.

Supposing it be required to run a service of trains at a maximum speed of 120 miles an hour. The advance on ordinary fast trains can be expressed by saying that the speed has to be doubled. It is well known that the most perfect and efficient brake at present used, namely, the air brake, falls off rapidly in efficiency as the speed increases. This is due to several causes. The kinetic energy of the moving train varies as the square of the speed, so that, if the braking force were constant for all speeds and were considered sufficient to bring the train to rest from 30 miles an hour within reasonable distance, then, from 60 miles an hour the train could be brought to a stop only in four times that distance. In reality, the mechanical friction varies inversely as the speed and the time that the brakes have been applied, so that at higher speeds, when a much greater braking force is needed, there is only a smaller one available. This is without taking into account the state of the rails,—a not unimportant factor in many cases.

In considering how a greater retarding force can be obtained, it is clear that from mechanical friction between wheels and brake blocks, or in fact anything depending upon the non-slipping of the wheels relative to the rails, no great increase of efficiency is to be hoped for. With electrically-driven high speed trains it is proposed to utilise the braking force obtained by working the driving motors as generators when retardation is required. This is done on some electric railways now in operation. It is an economical method of braking, for a great part of the energy of the moving train can be given back to the line; but, after all, it is only another method depending upon adhesion of wheels and rails. Further, if so much power is taken from the motor as a generator that the wheels have a continuous slip, or are on the point of slipping, it is evident that the same wheels cannot be efficiently used for the simultaneous application of friction brakes.

All electromagnetic brakes which produce their effects by means of friction or utilise magnetic effects to increase adhesion and so augment the friction, can be classed with the above as affording no hope of any great increase of brake power. In looking for other methods of reducing high speeds, it is evident, from physical principles, that the number of means depending on different physical properties is very limited, though the precise manner of their application can be almost endlessly varied. Among those methods which suggest themselves as likely are those depending on

I. Fluid friction (liquid or gaseous).

II. Electro-magnetic induction.

Some applications of the first method would be:—

(1) To make use of the surrounding medium,—the air,—by suddenly increasing the area of the moving surfaces of the train.

(2) To scoop up large quantities of water from channels either between, or at the sides of, the track, and convey it to a considerable height. Energy would be absorbed in raising and communicating velocity to the liquid, and the water could be got rid of as fast as it is taken up, so as not to increase the weight of the moving train.

(3) To make use of water projected at high pressure and, therefore, at high velocity, from mains laid parallel to the track, which water would be caused to impinge upon suitably shaped blades carried by the vehicles. Mechanically or magnetically controlled valves, short distances apart on the mains, would be operated from the moving trains, somewhat after the manner of the driving jets for the "Chemin de Fer Glissant" which was tried a few years ago.

(1) The first plan is obviously impracticable on a large scale and with long trains, and is now theoretically of less importance since the experiments of Mr. O. T. Crosby have shown that the air resistance is a function of the first power of the speed, instead of the second power. Nevertheless, it is proposed to utilise this method of braking on an experimental line to be operated at the Brussels exhibition, and a patent has been taken out for the method of extensible wings. The idea has been considered rather impracticable owing to the want of rapidity of action and the large area required as soon as the speed is reduced a little, and so was neglected. It has, however, advantages over (2) and (3) in that the braking mechanism itself is carried by the moving vehicles.

(2) This method also is impracticable, except over a limited distance and on level parts of the track, while the mechanical projections necessary would be a source of danger at high speeds.

(3) The third method would give considerable retarding force, but is a complicated one for high speeds and shares with the second plan the disadvantage of being costly.

In the induction method, use is made of electric currents, induced either in the rails on which the vehicles run, or in a special stationary conductor of copper, laid parallel to the rails, by electro-magnets carried by the vehicles. The retarding force is, in such a case, obtained without mechanical friction, and consequently the wear and tear to rails and wheels is greatly reduced.

One form of induction brake, which was invented a few years ago, seems to possess the chief requirements of a brake for high speeds, namely, great braking force which increases with the speed. This retarding force is obtained by means of electro-magnets held by the vehicles a short distance above the rails, with the line joining the poles parallel to the rails. Currents are induced in the head of the rails in a direction normal to their length by the rapidly moving magnets, and it is the generation of these eddy currents which produces the braking force.

The electrical difficulties of this brake have been surmounted, and from experiments which have recently been made it has been found that a retarding force equivalent to a coefficient of friction of about 0.2 would be obtainable at 60 miles an hour, this increasing, though not directly, with the speed. In the case of electrically driven vehicles the exciting current for the brake magnets could be taken from the power line. In such a case the rapidity of action of the brake would be very great.

If it were desired that the action of the brake should be independent of the contact with the power line, the magnets could be excited by the current from the driving motors used as generators, and just as these motors could be coupled in parallel at the high speed, and gradually put in series as the speed decreased, so could the brake magnets be put in series and parallel to suit the available current. These are, however, details into which it is not proposed to enter here.

In some calculations for an experimental car, weighing nearly forty tons, to be run at 150 miles an hour, it was estimated that the total braking force (friction brakes + motors run as generators + air resistance) would amount to only 8000 pounds, so that the minimum stopping distance would be over 7600 feet, and the time of stopping, about 100 seconds. If to such a car the induction brake were added, the distance run before the car would be brought to rest could be reduced to one-half or even one-third.

If the system were to be applied to ordinary railway trains drawn by steam locomotives, the exciting current could be best supplied by a dynamo carried by the train, either in the guards' van and belt-driven off an axle, or elsewhere and driven by a separate engine. The rapidity of action in such a case, though not equal to that obtainable by the above means, would be at least as great as that obtainable with the pressure air brake, while the braking force is so much greater at high speeds that the friction

brakes need not be applied till the speed is reduced to 30 miles an hour, except in cases of emergency.

Owing to the inefficiency of the induction brake at low speeds, it would, in all cases, have to be supplemented by some form of friction brake. Since, however, some form of air brake is fitted to all modern railway vehicles, the induction brake could be used for reducing from the higher speeds and after that the air brake could be applied. The danger and difficulty of stopping at the lower speeds is slight, but by a judicious combination of the two systems a high degree of safety could be obtained with saving to the rolling stock and rails, while for emergency stops, both, simultaneously applied, would give the sum of the separate retarding forces, as there would be no interference with each other's action. As before stated, a force equivalent to a coefficient of friction of 0.2 is obtainable at 60 miles an hour, and a greater force at higher speeds, but if the speed is diminished the brake becomes inefficient at about 25 miles an hour. This is one of the disadvantages of the system. Another is that the brake could not easily be made automatic in its action without the use of storage batteries on each vehicle.

As a set-off to these, the system appears to have several advantages among which the chief are—: Great reduction in distance required to reduce to quite a low speed; greater braking force than seems obtainable by any other means; braking appliances are carried by the moving cars; no mechanical connection between the brake and the high speed moving parts; retarding force independent of condition of rails.

It will be seen from the foregoing that the induction brake occupies a unique position and seems to hold out good prospects that in some form or other it will give to the world an increased braking efficiency for high speeds, thus rendering the use of such speeds not only possible, but safe.

SIR LOWTHIAN BELL, F.R.S.

A Biographical Sketch.

At the present day Sir Lowthian Bell is in the front rank of British metallurgical engineers and ironmasters and is well known, indeed, on the American side of the Atlantic as well. For many years he has been a prominent figure in the iron and steel industries, keenly alive to the importance of all the remarkable developments that have taken place in those branches in the last quarter century, and his contributions, both literary and directly practical, to blast furnace and steel works management have been many and varied.

Nearly half a century ago, after earlier years of study at the University of Edinburgh and on the Continent, he became connected with the chemical works at Washington, in the county of Durham, then in the hands of his father-in-law, the late H. L. Pattinson, and under his direction they were much enlarged and an extensive establishment was erected for the manufacture of a paint pigment discovered by Mr. Pattinson.

At about the same time, and in company with his brothers, Thomas and John, Sir Lowthian founded the Clarence Iron Works on the Tees, one of the earliest, and now one of the largest, metallurgical establishments on that river, and carried on in connection with extensive collieries and iron ore mines. While most actively engaged in this enterprise he has still found time for much outside work, a goodly portion of which

is found in the shape of contributions to the various engineering societies of which he is a member, among them the Iron and Steel Institute, of which he has been president, the Institution of Mechanical Engineers, the Society of Chemical Industry and others. For his distinguished services to science and industry he was made a baronet in 1885.

During one of his several visits to the United States Sir Lowthian carefully investigated the conditions of iron making in the South, especially in Alabama, and predicted, at the time, that iron would be cheaper there than anywhere else in the world. He acted as a juror at the Centennial Exposition at Philadelphia in 1876 and served similarly at the Paris Exposition of 1878.

Politically, also, Sir Lowthian has been active, having been twice elected Mayor of Newcastle-on-Tyne and member of Parliament for Hartlepool. In later years, however, he has devoted himself almost altogether to his profession.

Current Topics.

THE degree of accuracy attainable in modern naval gunnery in actual warfare is something yet to be determined. With the exception of the battle of the Yalu during the Chino-Japanese war, there has been no opportunity for finding out what might be accomplished at long range by a modern gun, mounted on so unstable a platform as the deck of a rolling vessel; and the value of the Yalu fight as an object lesson in this respect was impaired by the relatively unskilled character of the gunners. Certain it is that while death and destruction were meted out all around in that encounter, an enormous amount of ammunition was used up in the work. The bombardment of Alexandria by the British fleet in the early eighties afforded none of the conditions of a sea fight, since the vessels were at anchor in practically smooth water and their target certainly was immovable enough; and even there the expenditure of powder and shell was out of all proportion to the damage inflicted. The point has recently been made, however, that, after all, it is astonishing that a ship is ever struck by a projectile from a gun, and that there is probably more luck than cunning in the art of modern naval warfare. In a lecture at the United States Naval War College, at Newport, Professor Alger, a short time ago, stated, for example, that at a convenient fighting distance, say 2000 yards, a modern

battleship, like the *Indiana*, of the United States Navy, appears to be of the same size as a picture of her, eight-tenths of an inch long, held at the point of clear vision, about 14 inches from the eye, while the outlines of the real ship will be much less clear and distinct than those of the picture. The height would, of course, appear to be still less, so that the difficulty of hitting such a target, even with the ship at rest and the gun in a fort, instead of both moving more or less rapidly, can be appreciated at least to some extent. The element of luck truly must enter largely into effective fire under such conditions.

WORKINGMEN'S strikes very often bring to light unreasonable trades union rules which are at the bottom of much mischief. The engineering dispute now waging in Great Britain between the Amalgamated Society of Engineers and their employers recalls at least one of them,—that each machine tool must be "attended" by only one man, instead of letting this one operative give his care to, say, half-a-dozen tools, like, for instance, a planing machine or lathe which frequently, for quite long periods of time, require very little attention while at work. In the United States, and in Germany and France, too, this one-man-to-a-machine policy would not be tolerated for a day. The machinist's time is too valuable to be dawdled away in sitting on a bench mayhap, waiting for a big surface to be planed off or turned down; the principle of maximum output with minimum labour demands that the time be more profitably employed, and this it can be without imposing hardship on the men. A number of machine tools can often be tended with little more trouble than a single one, and carrying this into practice has helped largely to make American shops so remarkable in productive capacity without sacrifice of quality. If the present labour dispute in Great Britain should bring about the abolishment of some of these foolish regulations, an important point would be gained for all,—not simply for the employers. Rules, like this one, paralyse trade, eventually drive it away to other countries, and the ill effects fall upon employer and employed alike. For some years past Continental, and principally German, competition has been a serious menace to British industries, and a successful issue for the men in the present agitation, which has been veiled as an "eight hours movement," but which is really a demand for increased wages with the retention of all the evil influences of befogged trades unionism, would, in the end, probably be a rather doubtful victory for them. Trade depression means lack of orders, closed shops, and idle days for the men, and the loss of wages for these days might more than wipe out the increase now under contention.

TEN large freight locomotives have recently been ordered by the Chicago and Northwestern Railway, in the United States. These will be six-wheel coupled engines with cylinders 19"x26", and a boiler pressure of 190 pounds to the square inch. The driving wheels will be 63 inches in diameter, and will carry 116,000 pounds, the total weight of one of these engines in working order being 153,000 pounds. A locomotive of this class will, therefore, have a tractive force of 19,815 pounds, or a power of hauling on the level, inclusive of the weight of engine and tender, 3,170 tons of 2000 pounds. While these locomotives are not so powerful as the new passenger engines of the Southern Railway, alluded to in last month's issue of CASSIER'S MAGAZINE, they are each a ton and a half heavier in gross weight, and have the same adhesive weight (116,000 pounds) on the driving wheels. It speaks well for the bridges and track of the Chicago and Northwestern Railway that its officers are not afraid to put engines of this weight on them; but, still, the increasing weight of freight and passenger locomotives suggests that there must be an economical limit to it some time. It is much easier to justify

very heavy freight locomotives than passenger engines. In the former case, there is either no fixed time schedule, or, if there is, enough freight cars are always awaiting transportation to make up a full load. But there is usually a preponderance of freight to be carried in one direction, as compared with the other, in the United States, so that if fifty loaded cars were a full train for one of these engines, in one direction, it might be expected to haul 100 empty freight cars on the return trip. This, in turn, means a considerably increased risk of broken draw-bars on the return trip, with the probability of a divided train, a blocked road or a fatal accident among the consequences.

No doubt there are certain obvious advantages in massing freight or passengers in the largest practicable units for transportation. It reduces the cost of train crews; it increases the proportion of live to dead loads; it tends to keep the line clear by lessening the number of trains; with a heavy locomotive, kept in good repair, it minimises the chances of being stuck on an up-grade, or of a break-down anywhere. But economy in one direction often means extravagance in another. The new steel bridges necessary to bear such heavy locomotives cannot be substituted for their wooden or iron predecessors without a large outlay; a 90 or 100-pound rail always costs more than a 70-pound one; ties, though creosoted, are not everlasting, while the price of timber is steadily advancing; ballast, if knocked out or hammered down, needs hands to replace it. Moreover, while the hauling power of a heavy locomotive may be closely calculated before it has travelled a single yard under its own steam, the damage it may do a permanent way cannot be told except by ten or twenty years' observation. And, again, there is not a single railroad of any size in the United States to-day which has its system throughout laid with the class and weight of rail which it has finally adopted as suited to its traffic. So that it will not be until at least the year 1900 that the new rails will be uniform in weight, and thus give the engineer in charge of the roadbed some definite data to work upon. One can hardly venture to say, from present premises, what the outcome of the struggle between locomotives and permanent way will be, but it is likely that the great main lines will be levelled and straightened until even the largest practicable trains can be hauled over them by locomotives of moderate weight and dimensions, the exceptionally stiff pieces of road being reserved in divisions by themselves and worked by "grade climbers," as they used to be called. This seemed to be the late President Newell's object when he straightened and levelled the main line of the Lake Shore and Michigan Southern—a road which had very great natural advantages to begin with—and the result to-day is that locomotives on that line draw larger trains with less effort than those of any other road of similar importance in the whole United States. With improved tracks will come lighter passenger cars, since a considerable percentage of the weight of the parlour and sleeping cars now in use, is added to keep the body of the car in equilibrium, while the inequalities of the track, transmitted through the wheels, are taken up by the springs. If we always remember that the theoretically ideal track and train would be perfectly smooth, level and straight rails, and carriages and locomotive in the form of an absolutely rigid horizontal cylinder mounted on frictionless wheels without springs, we shall be better able to judge how far practical working conditions approximate to an ideal standard.

WITH the apparently serious attention that is about to be given to chainless bicycles, the question of what benefit is to be expected from them becomes a somewhat interesting one. Novelty they will have, to be sure, but this will soon wear off; in some of the chainless designs, too, the transmitting mechanism will be protected by more or less dust-

proof coverings, and this certainly will be a good point, though the same can be attained with the conventional chain by suitably encasing it as is commonly done on British cycles. So far as merit otherwise is concerned, however, the chainless wheel at present seems to have nothing to commend it. All experience thus far indicates that no form of bicycle gear yet devised equals the best chain for efficiency and durability.

ONE of the big American steel companies has adopted electro-magnets as the most convenient means of picking up and transferring plates of iron or steel from one part of its mill to another. These magnets correspond in shape to the now almost forgotten horseshoe pattern, the poles being elliptical in cross-section, measuring 3 inches by 24 inches across the axes, and being 7½ inches apart. In depth, each pole measures 10 inches, 7½ inches of which are covered by the magnetising coils with a uniform thickness of one and a half inches. To insure protection against dampness, and consequent deterioration of the insulation, these coils are inclosed in a watertight brass casing, while for protection against mechanical injury, the whole magnet—poles, end piece and coils—is boxed in with half-inch steel casing. A five-ton load requires a current of only 4 ampères at 240 volts to lift it, and the makers of the magnet claim that there is no more danger of its dropping its load suddenly than there is with any other kind of crane attachment. This statement one can well believe, in view of the dangers which have been groundlessly predicted for almost every other new application of mechanical or electrical power. During the past few years, while the erection of tall buildings has been going on very rapidly in New York City, for example, we remember the case of at least one heavy girder which slipped out of its sling at an altitude of over a hundred feet; but as, most fortunately, no one was killed by its descent, the newspaper noise which followed soon subsided. The only chance of a slip with a magnet is temporary failure of the current, which is becoming less and less liable to happen as improvements in the electrical art continue. In another aspect, the use of the magnet to move steel beams raises some interesting questions. As each beam so lifted, being of steel, will retain a considerable proportion of the magnetism imparted to it, what unforeseen effects may it have when placed in, say, an office building where its magnetism is lost sight of or neglected? Will it cause impedance in the electric currents used for lighting such a building? Will it stop clocks placed within its influence by magnetis-

LIFTING MAGNETS AT THE PLATE MILL OF THE ILLINOIS STEEL COMPANY, AT SOUTH CHICAGO, ILL.

ing their springs? It seems likely enough that such results, as well as others not counted upon, may follow from the use of magnetised steel beams.

THE thin glass tumblers which have recently been put on the American market in such enormous quantities have surprised many a housekeeper by cracking suddenly while standing on the shelves. It has needed ocular demonstration to convince some housekeepers that tumblers could behave in this manner. When one of these tumblers is found cracked, the first thought is that a careless servant must be in fault. Hot water or rough handling was always the cause of the breakage of the old-fashioned flint glass goblets. The difference between the old and the new kinds of tumblers seems to be in the haste with which the latter is prepared, thus necessitating a very short stay in the annealing furnace. The molecules of the glass in this case have no chance to arrange themselves in lines of least strain, so that every new-fashioned tumbler is filled with torsion stresses tending to fracture its substance with any slight external aid—as, for example, the cool air from an open window striking the proximate sides of the tumblers set on a dining room table. Of course, the advantage of using the new kind of tumblers is that their cost is only one-fifth or one-sixth of the old kind. Looking at the matter more broadly, the tendency of the new glasses to spontaneous fracture is only another illustration of crystalline degeneration. Herbert Spencer, in perhaps the most fascinating chapter on evolution which he has ever written, points out that all substances which have been rendered colloid by the application of heat sooner or later radiate this heat, which has been acting as a cement between the molecules, and become crystalline. Mr. Spencer gives as illustrations of this process the igneous rocks in their various stages, from molten lava to granite, and jam, which becomes gritty when kept too long, owing to the crystallisation of the contained sugar.

WE sometimes hear of inventions which have appeared "before their time," and it may be of interest to consider just what it means for an idea to have come into the world before conditions are ready for it. Every one who has had to do with the Patent Office knows what is meant by the "state of the art," and one of the first duties of an examiner is to investigate the status of general knowledge and practice in that branch of applied science to which the application belongs. In such cases, however, the intention is to discover, if such be the case, whether the invention has not been anticipated by some device or method in general use. On the other hand, it may sometimes be most important to know whether or no the "state of the art" is far enough advanced to enable the idea to be utilised or applied, as upon this very question the practical fate of a device often depends. Many ingenious and patient men have worked persistently to develop inventions for which the art was not ready, but which, in later years, when materials, methods and markets had developed, proved to be fully as valuable and important as had originally been anticipated.

THE pneumatic bicycle tire would be of little value if the rubber industry were not equal to the production of the proper material from which to make it, and the motor carriage is, in like manner, dependent upon the parallel development of the storage of energy. Professor Langley has shown us how to meet the essentials of a successful flying machine, and now calmly throws the burden of the commercial success of the problem upon the builders of motors by telling them to go ahead and produce a source of motive power which shall be at the same time powerful enough and light enough to drive his aeroplane without overweighting it. Similar conditions often confront students of applied science, and in many cases brilliant ideas have proved commercially worthless simply because of the practical im-

possibility of realising the constructive conditions. There is little doubt that it would prove a most profitable occupation for thoroughly informed specialists to make a study of neglected inventions upon which the patents have expired, and which have never been developed for the above reasons, bringing to this revival of past ideas the present possibilities in the light of more recent developments in science and construction.

At last some data are forthcoming on the comparative cost of the overhead trolley, the slotted conduit trolley and compressed air, under circumstances which should guarantee their approximate correctness. The special committee of the City Council of Liverpool, England, which was appointed several months ago to inquire into the best means of improving the local street car system, employed, among others, Mr. F. S. Pearson, the chief engineer of the Metropolitan Traction Company, of New York City, to furnish his opinion, accompanied by such facts and statistics as he deemed necessary. The gist of Mr. Pearson's report is contained in the following table:—

	Cost of operation per car-mile.	Cost of operation per year on the basis of 180,000 car miles per mile of track.
	d.	£
Overhead trolley	3.68	138,000
Slotted conduit	4.00	150,000
Compressed air	5.02	188,250

Thus, according to Mr. Pearson, whose position gives him access to all the data necessary for making an accurate judgment, the cost of operating the overhead trolley is only 8 per cent. less than that of the slotted conduit, while the cost of compressed air is 26 per cent. more than that of the slotted conduit. The cost of installing the slotted conduit system above that of the overhead trolley is £5000 a mile, according to Mr. Pearson's report, and the cost of maintenance, as distinguished from that of operation, would also be somewhat larger. But if we consider that the slotted conduit, or underground trolley as it is more familiarly called, has been installed in only a small part of New York City for the past two years, so that the possibilities of its economical working on a large scale are only beginning, we shall see reason to believe that this mode of distributing the electric current for car propulsion purposes has a great future before it. The slotted conduit system has the undoubted advantages of the absence of overhead wires, in being sightly, and in not giving rise to electrolysis by imperfect return-rail circuits. It is a characteristic note of the trend of events that cable traction was not seriously considered by the special committee of the Liverpool Council, while Sir David Radcliffe, for purposes of comparison, gave the present cost of horse traction in Liverpool at 7.19d. per car-mile, or more than double that of ordinary trolley traction.

A writer in a Japanese paper directs attention to the necessity of providing a dockyard in that country, capable of turning out the heaviest class of work, if she is to dispense with foreign assistance for the building and maintenance of her navy. At present Japan possesses only one dockyard fit for building or repairing warships of the first class, —that at Yokosuka,—and only one of the three dry docks there could receive such ships as the *Yoshino* and *Fuji.* The mikado's government has displayed a determination to render Japan independent of European aid for all military and naval purposes—to accept it only as a temporary expedient which must be replaced by native labour and administration as speedily as possible. From a naval point of view, therefore, a new dockyard, adapted in all ways to modern requirements, and with sufficient dry dock accommodations, seems imperative. The principal difficulty appears to be the financial one, and the writer in question suggests selling some of the State railways to provide the necessary funds. Such a sale is, however, so contrary to the policy hitherto pursued by the Japanese government that it is

doubtful whether it will ever be attempted. But should the money be obtained by that, or any other means, a considerable portion of it will be transferred to America and Europe for the first outfit of machinery and machine tools. The Japanese are scarcely prepared at present to undertake such an equipment within reasonable time, although they will undoubtedly copy it afterwards.

WOMEN, performing the most exacting manual labour by the side of men, have, in the United States, always been regarded as peculiar social outgrowths of the older countries of the world. Female factory labour of the lighter kind, in spinning mills, for example, and in various other establishments handling comparatively delicate materials, there is in plenty in America, but the introduction of girls as machine shop hands, operating milling machines, drill presses and similar tools, is an innovation only recently effected and likely to be generally deprecated. Girls are so employed, it is stated, in one of the American bicycle factories, with the view of securing cheaper labour than its competitors, and the wish is to be heartily echoed that the experiment will prove unsatisfactory in results and will be speedily abandoned. There are so many avenues to self-sustaining legitimate employment open to girls and women,—employments, too, for which they are better suited than men,—that their introduction into the machine shop can have nothing to commend it. It is a species of degradation of woman from which American industries have, happily, been almost altogether free, and which, Americans should hope, will never gain a foothold in their country.

THE heaviest open-hearth gun ingot ever cast was recently turned out at the works of the Bethlehem Iron Company. According to particulars given in the *Bulletin* of the American Iron and Steel Association metal from three furnaces was required to fill the mould. The ingot weighed 223,000 pounds, or nearly 100 gross tons. It was octagonal in shape. Its length was 16 feet 10 inches and its diameter, 74 inches. The ingot will be forged into a tube for a 16-inch experimental nickel steel gun which the Bethlehem Company are to make for the United States army. The forged tube will be 35 calibres, or 46.6 feet, in length. The jacket for the gun will require an octagonal ingot of even greater weight, namely, 243,000 pounds, or 108 gross tons. Even these large masses of steel have been exceeded in the rectangular ingots cast at Bethlehem for armour plate, the 17-inch port plates for the two turrets for the 12-inch guns of the United States battle ship *Iowa* having required nickel steel ingots weighing 273,500 pounds, or 122 gross tons.